+1293°C

-163°C

+1093°C

-1018°C

INSTRUCTION MANUAL

-1

+2183°F

+1277°F

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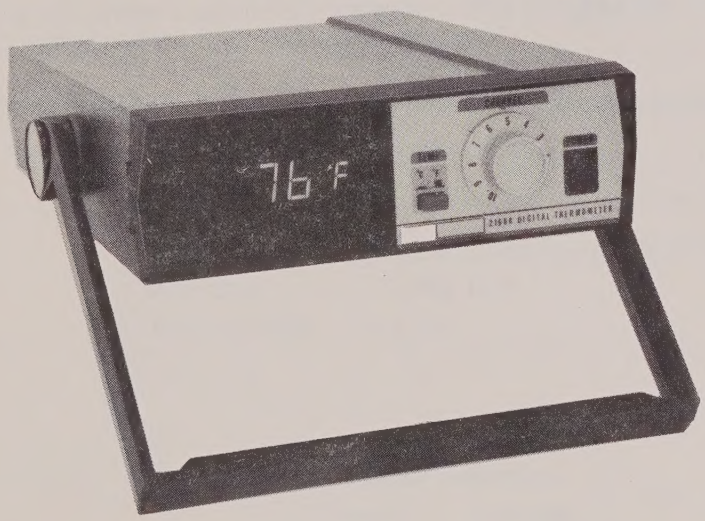

MODEL

2166A

MULTIPOINT DIGITAL
THERMOMETER

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Change/Errata Information

Issue No: 5 7/79

This change/errata contains information necessary to ensure the accuracy of the following manual. Enter the corrections in the manual if either one of the following conditions exist:

1. The instrument's pcb revision letter is equal to or higher than that which is indicated at the beginning of the change.

2. No revision letter is indicated at the beginning of the change/errata.

MANUAL

Title: MODEL 2166A MULTIPOINT DIGITAL THERMOMETER
Print Date: APRIL 1976
Rev and Date: 1-2/77

C/E PAGE EFFECTIVITY

Page No.	Print Date
1	7/79
2	7/79

CHANGE #1–11434

Rev-H, A1A1 Thermometer PCB Assembly

On page 5-6, add CR4 to reference designators CR6 thru CR15, and change total quantity from 10 to 11.

On page 5-7, change the stock number, supply code, and part numbers for Q27 and Q28 from:
272237, 07263, 2N4946
to:
477331, 04713, MPSU01A

On page 8-3, add diode CR4 between the +5 and +6.8V dc power supply outputs; cathode to +6.8V, anode to +5V.

CHANGE #2–11563

Rev H-1, A1A1 Thermometer PCB Assembly

On page 5-8, make the following changes:
Change the U1 entry from:
IC, dual opnl ampl; 404087; 49956; RC4739DP; 1; 1
To:
Op amp pcb assy; 488379; 89536; 488379

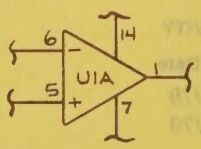
Add the following new entry (socket for U1):
XU1; Socket; IC, 14-pin DIP; 276527; 89536; 276527; 1; 1

Rev-J, A1A1 Thermometer PCB Assembly

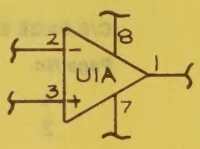
On page 5-8, change the entry for U1 from:
IC, dual opnl ampl; 404087; 49956; RC4739DP; 1; 1
To:
IC, dual opnl ampl, 8-pin DIP; 478032; 04713; MC4558NCPI; 1; 1

On page 8-3, Figure 8-2, make the following changes:

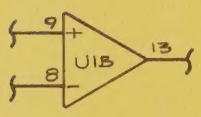
FROM:



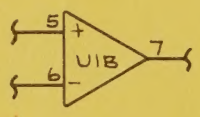
TO:



FROM:



TO:



ERRATA #1

On page 4-2, make the following changes:

Replace paragraph 4-14 with the following:

4-14. If the A21-5 Voltage Divider is ordered, it should be noted that it consists of two precision resistors with no test fixture. The user will be responsible for configuring the resistors as the appropriate voltage divider.

ERRATA #2

The following information pertains only to the 2160A-04 AOU manual.

On page 604-1, paragraph 604-4, make the following changes:

FROM: Linearity . . . . . ±0.5% of Full Scale
TO: Accuracy . . . . . ±0.5% of reading ±1 mV

ERRATA #3

On page 5-3, Final Assembly, make the following changes:

FROM: 2/Case, molded plastic/432500/89536/432500/1
TO: 2/Case, molded plastic/432526/89536/432526/1

CHANGE #3-12437

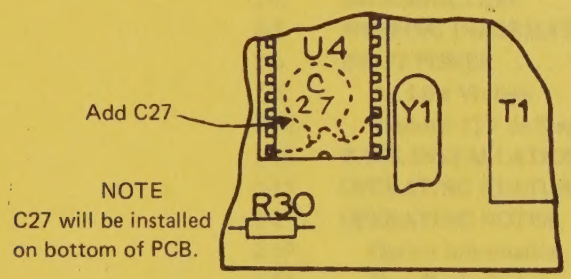
Rev.-J-1. A1 A1 Thermometer PCB Assembly (2166A-4001)

NOTE
The information contained in this change (#3) will apply ONLY to the 2166A-4001 PCB's stamped "J-1", earlier and later revisions will not be affected.

On page 5-6, make the following changes:

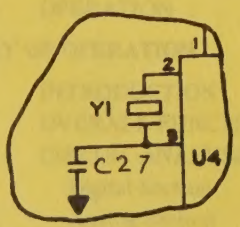
ADD: C27/Cap, Mica, 82 pF +/-1%, 500V/271957/72136/DM15F820F/1

On page 8-2, Figure 8-1, make the following changes:



On page 8-3, Figure 8-2, make the following changes:

ADD: Capacitor C27 between U4-3 and ground



U4
T1
Y1
R30

Y1
U4

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Section 1
Introduction & Specifications

1-1. INTRODUCTION

1-2. The Model 2166A Multipoint Digital Thermometer is a portable four-digit, manual-scan, thermocouple thermometer capable of measuring any 1 of 10 possible like-type thermocouple inputs and resolving 1°C or 1°F over a temperature range of –200 to +2328°C or –328 to +3999°F. It features switch selection of temperature (°C/°F) and thermocouple channel (1-10), a four digit LED display, reference junction compensation (to eliminate the need for an ice bath reference junction), the choice of any one of eight thermocouple types (J, K, T, E, R, S, B or C) as the input device, dual-slope measurement techniques, digital linearization of thermocouple inputs, and power inputs for both ac line and external 12V dc operation. Several options and accessories are also available for use with the 2166A.

1-3. Front panel switch controls include a push-button power switch (ON/OFF), a push-button temperature select switch (°C/°F), and a 10-position rotary switch for selecting the desired thermocouple. The rotary switch is labeled CHANNEL Select and the thermocouple inputs are identified as 1 through 10.

1-4. The front-panel display consists of five, seven-segment, high-intensity LED's, and features leading zero suppression. Four of the LED's are used to display numeric data, including a minus sign for negative temperature indications. The fifth LED displays the selected °C or °F scale character. An open-thermocouple detector causes the display to blink when an open circuit is sensed at any one of the selected thermocouple input terminals.

1-5. A plug-in module at the rear of the 2166A provides 10 pairs of screw-type input terminals for attaching individual thermocouples to the desired channels. These terminals are an integral part of an isothermal block and serve as the reference junction for the reference junction compensator. (The reference junction compensator provides the physical and electrical equivalent of, and eliminates the need for, an ice bath junction at 0°C or 32°F.)

NOTE

All thermocouples connected to the input terminals must be of the same type.

1-6. The actual measurement range of the 2166A is determined by the type of thermocouples being used as the input devices. Any one of eight thermocouple types can be used; J, K, T, E, R, S, B or C. To ensure the proper linearization of the selected thermocouple input, a corresponding linearization program must be selected on the interior of the unit. Selection is accomplished by installing a type select pcb which corresponds to the input thermocouple. A single type select pcb is supplied with the unit to match the thermo-

Table 1-1. 2166A ACCESSORIES

MODEL NO.	DESCRIPTION
C80	Carrying Case
C86	Carrying Case
TJ36-J	J-Type Thermocouple Probe
TJ36-K	K-Type Thermocouple Probe
TJ36-T	T-Type Thermocouple Probe
M00-100-714	Front Panel Dust Cover
M00-200-611	Rack Mounting Kit, Offset
M00-200-612	Rack Mounting Kit, Center
M00-200-613	Rack Mounting Kit, Side-by-Side
2160A-7016	J-Type Select PCB
2160A-7017	K-Type Select PCB
2160A-7019	E-Type Select PCB
2160A-7018	T-Type Select PCB
2160A-7012	R-Type Select PCB
2160A-7013	S-Type Select PCB
2160A-7014	B-Type Select PCB
2160A-7015	C-Type Select PCB
2160A-7022	Interface Cable

couple specified at the time of purchase. The remaining pcb's are individually available as accessories and are described in Table 1-1.

1-7. Accessories and options available for use with the 2166A are listed and described in Tables 1-1 and 1-2, respectively. Both options are field installable. Either one, but not both, of the options can be installed in a unit. Detailed information concerning each option and accessory is given in Section 6 of this manual, Option and Accessory Information.

1-8. The 2166A is designed to operate from either ac line power or an external 12V dc source. A choice of any one of three line power configurations are available: 100V ac, 50 to 440 Hz; 115V ac, 50 to 440 Hz; and 230V ac, 50 to 440 Hz. Specify the required configuration at the time of purchase.

Table 1-2. 2166A OPTIONS

OPTION NUMBER	DESCRIPTION
–02	Digital Output Unit
–04	Analog Output Unit

1-9. SPECIFICATIONS

1-10. Specifications for the 2166A are given in Table 1-3.

Table 1-3. SPECIFICATIONS

ELECTRICAL

Compatible Thermocouple Types	Unit can be calibrated to operate with any one of the following thermocouple types: J, K, T, E, R, S, B or C
Measurement Method	Dual-slope integration over a 100 ms period
Zero Drift	None. Automatic zero correction
Reading Rate	2.5 readings per second
°C to °F Conversion	Switch selectable
Input Characteristics	
Input Connections	Screw terminals on isothermal connector
Input Circuit	Two-wire isolated per channel, 10-channel, switch selectable
Input Impedance	$> 100\ M\Omega$
Input Current	< 500 pA
Source Impedance	$\leq 5k\Omega$. $5k\Omega$ causes $<0.2°C$ (.36°F) error with k thermocouple
Overload	Display flashes when input voltage exceeds full-scale temperature range
Open Input	Display flashes to indicate open at input terminals
Maximum Input Voltage	130V dc or 130V ac (rms) between any pair of inputs
Maximum Input Voltage (without damage)	400V dc or ac peak continuously between inputs or between either input and ground
Maximum Common Mode Voltage (without damage)	400V dc or ac peak
Common Mode Rejection	$\geq$ 120 dB @ 50, 60, 400 Hz $\pm$0.1% with $1k\Omega$ source impedance unbalance
Normal Mode Rejection	$\geq$ 60 dB @ 50, 60, 400 Hz $\pm$0.1%
Accuracy	See Table 1 for °C specifications and Table 2 for °F specifications
Response Time to Rated Accuracy	$<$ 2.0 seconds
Linearization	Digital with eight selectable programs in LSI ROM
Linearization Programs	
J, K, T and E	32 straight line segments for positive inputs and 16 for negative inputs

Table 1-3. SPECIFICATIONS (Cont.)

Reference Junction Compensation

20 to 30°C (68 to 86°F)

J, K, T, E . . . . . 0.025 degrees per degree

0 to 20°C, 30 to 50°C (32 to 68°F, 86 to 122°F)

J, K . . . . . 0.032 degrees per degree

T, E . . . . . 0.045 degrees per degree

Temperature Coefficient . . . . . 0.005% of reading per °C

Internal Temperature Rise . . . . . ⩽8°C (14.4°F)

Table 1. ACCURACY SPECIFICATIONS °C

THERMOCOUPLE TYPE	TEMPERATURE RANGE °C	RESOLUTION AND REPEATABILITY (±C)	APPLICABLE TEMPERATURE RANGE °C	MAXIMUM ERROR INCLUDING NBS CONFORMITY (±°C)*				
				CALIBRATION ACCURACY	20 min. to 24 hrs. 23 to 27°C	90 Days 20 to 30°C	1 Year 15 to 35°C	NBS CONFORMITY (±°C)
J	−200 to 778	1	−200 to 0	1	1	1.5	1.5	.19
			0 to 778	1	1	1	1.5	.15
K	−200 to 1356	1	−200 to 0	1	1	1.5	2	.20
			0 to 1356	1	1	1.5	2	.18
T	−200 to 400	1	−200 to 0	1	1	1.5	2	.19
			0 to 400	1	1	1	1	.15
E	−200 to 1000	1	−200 to 0	1	1	1.5	2	.17
			0 to 1000	1	1	1	1.5	.18
R	0 to 1778	1	0 to 1778	1.5	1.5	2.5	3	.26
S	0 to 1778	1	0 to 1778	1.5	1.5	2	3	.22
B	533 to 1844	1	533 to 1844	1.5	1.5	2	2.5	.29
C	0 to 2328	1	0 to 2328	2	2	3	3	.36

* Includes reference junction and conformity errors. Excludes thermocouple errors.

Table 1-3. SPECIFICATIONS (Cont.)

Table 2 ACCURACY SPECIFICATIONS °F

THERMOCOUPLE TYPE	TEMPERATURE RANGE °F	RESOLUTION AND REPEATABILITY (±°F)	APPLICABLE TEMPERATURE RANGE °F	MAXIMUM ERROR INCLUDING NBS CONFORMITY (±°F)*				NBS CONFORMITY (±°F)
				CALIBRATION ACCURACY	20 min. to 24 hrs. 72 to 82°F	90 Days 68 to 86°F	1 Year 59 to 95°F	
J	–328 to 1432	1	–328 to 32 32 to 1432	1.5 1.5	2 1.5	2 1.5	3 2.5	0.27 0.2
K	–328 to 2472	1	–328 to 32 32 to 2472	2 1.5	2 1.5	2.5 2.5	3 3.5	0.28 0.26
T	–328 to 752	1	–328 to 32 32 to 752	2 1.5	2 1.5	2.5 1.5	3.5 2	0.3 0.2
E	–328 to 1832	1	–328 to 32 32 to 1832	2 1.5	2 1.5	2.5 2	3.5 3	0.25 0.25
R	32 to 3232	1	32 to 3232	2.5	2.5	4	5	0.4
S	32 to 3232	1	32 to 3232	2.5	2.5	4	5	0.33
B	1032 to 3352	1	1032 to 3352	2.5	2.5	4	4.5	0.45
C	32 to 3999	1	32 to 3999	3	3	5	5.5	0.58

*Includes reference junction and conformity errors. Excludes thermocouple errors.

GENERAL

Type of Display . . . . . LED, 0.56 in high.

Power Requirements

Line Operation . . . . . 115V ac ±10%, 50 to 440 Hz, 8W. 100V ac and 230V ac version are also available.

External DC Source . . . . . 11 to 15V dc @ 400 mA

Size . . . . . 2.52 in (H) x 8.55 in (W) x 9.9 in (D) (6.40 cm x 21,72 cm x 25,15 cm). See Figure 1-1.

Weight . . . . . 3 lbs. 4 oz. (1.47 kg)

Table 1-3. SPECIFICATIONS, Cont.

ENVIRONMENTAL

Temperature

Operating	0 to 50°C (32 to +122°F)
Storage	–40 to 75°C (–40 to 167°F)

Humidity

0 to 50°C (32 to 122°F)	80% non-condensing
0 to 35°C (32 to 95°F)	90% non-condensing

Shock and Vibration . . . . . Meets requirements of MIL Standard 810

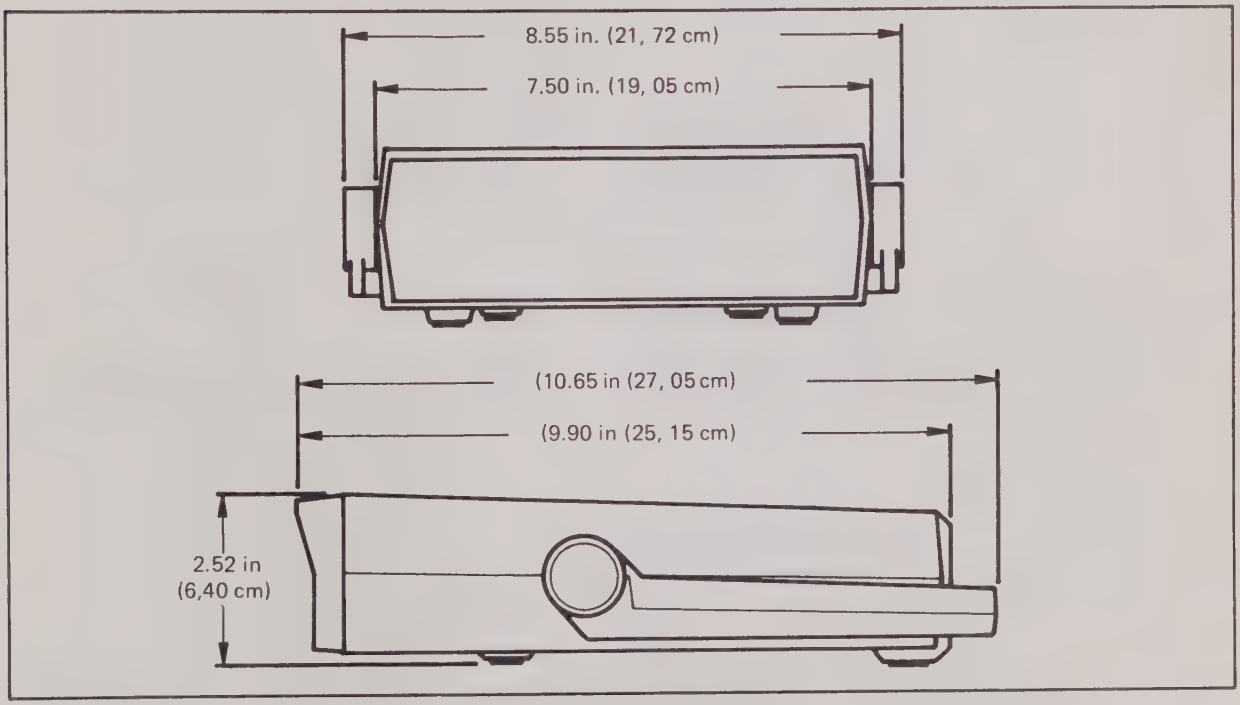

Figure 1-1. OUTLINE DRAWING

Section 2
Operating Instructions

WARNING!

Due to the possible presence of lethal voltages, the procedures in paragraphs 2-21 and 2-27 should be performed by qualified personnel only.

2-1. INTRODUCTION

2-2. This section of the manual contains information regarding installation and operation of the Model 2166A Multipoint Digital Thermometer. It is recommended that the contents of this section be read and understood before any attempt is made to operate the instrument.

2-3. SHIPPING INFORMATION

2-4. The 2166A is packaged and shipped in a foam-packed container. Upon receipt of the instrument, a thorough inspection should be made to reveal any possible shipping damage.

2-5. If reshipment of the instrument is necessary, the original container should be used.

2-6. INPUT POWER

2-7. The 2166A can be operated from either ac line power or an external 12V dc source. The unit is energized when either or both sources are connected to their proper input terminals, and the front-panel POWER switch is set to ON.

2-8. AC Line Voltage

2-9. The 2166A is factory wired to operate from one of three ac line voltages. These are: 100V ac, 50 to 440 Hz; 115V ac, 50 to 440 Hz; and 230V ac, 50 to 440 Hz. Before connecting the 2166A to the ac line, check to ensure that the instrument is wired to accommodate the local line voltage. A decal on the underside of the unit defines the particular line voltage required to operate the instrument.

2-10. The rear panel ac input connector is a three-prong, U-ground connector which permits the instrument to be connected, via the power cord, to the appropriate line voltage. The offset prong on this connector is connected to the 2166A power supply, and should be connected through the power cord to a high quality earth ground.

2-11. External 12V dc Source

2-12. The external 12V dc source connects to two screw terminals provided on the rear of the 2166A. The decal on the bottom of the unit defines their location and polarity. The external source should be capable of supplying at least 400 mA at 11V dc.

2-13. RACK INSTALLATION

2-14. The 2166A is designed for field and bench-t
or for installation in a standard 19-inch equipment r
an accessory rack-mounting kit. Kits are available fo
right, center or side-by-side mounting of the 2166A. Information about the rack mounting accessories is given in Section 6 of this manual, Option and Accessory Information.

2-15. OPERATING FEATURES

2-16. The location of all 2166A controls, indicators and connectors are shown in Figure 2-1, and described in Table 2-1.

2-17. OPERATING NOTES

2-18. The following paragraphs describe various conditions which should be considered before operating the 2166A.

2-19. Option Information

2-20. Supplementary operating instructions are necessary when operating a 2166A which is equipped with one of the available options. Detailed information regarding the operation of each available option is given in Section 6 of this manual, Option and Accessory Information

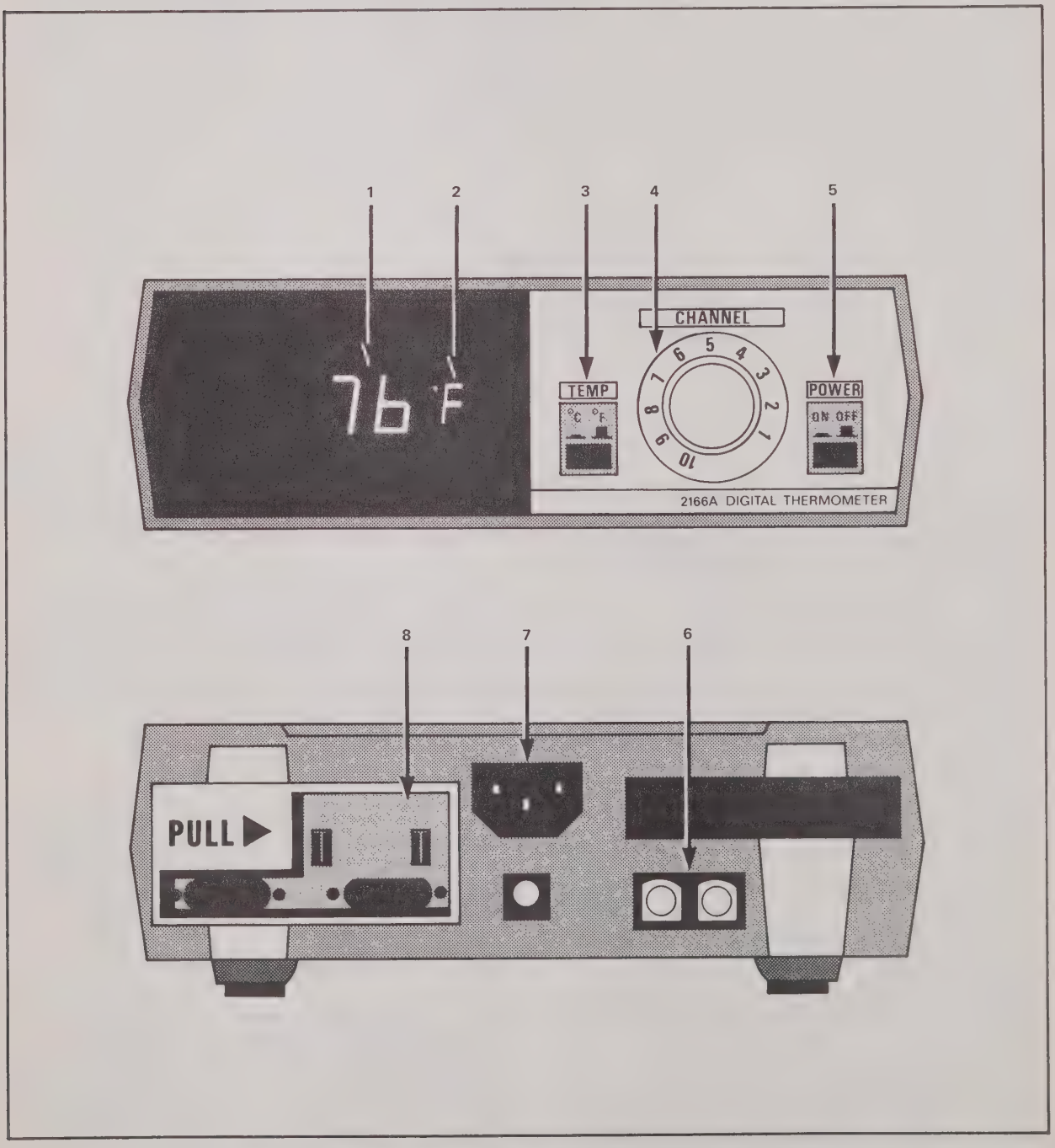

Figure 2-1. 2166A CONTROLS, INDICATORS AND CONNECTORS

Table 2-1. 2166A CONTROLS, INDICATORS AND CONNECTORS

REF. NO.	NAME	FUNCTION
1	Digital Display	Displays a four digit readout of the measured input temperature. Leading-zero suppression is also included. A minus sign is displayed for negative temperature measurements. The absence of a polarity sign indicates a positive temperature measurement.
2	Temperature Scale Indicator	Displays the temperature scale represented by the digital display data; °C or °F.
3	TEMP Scale Switch	Selects the temperature scale for the digital display. When the switch is depressed (IN), the °C scale is selected. The °F scale is selected when the switch is released (OUT).
4	CHANNEL SELECT Switch	Selects 1 of 10 possible thermocouple inputs to be used as the thermometer input. The temperature of the selected thermocouple is continuously read and displayed.
5	POWER Switch	Switches the 2166A on or off regardless of the input power source. The instrument is turned-on when the switch is depressed.
6	External 12V dc Input	Provides screw-type input terminals for connecting an external 12V dc power source. The 12V dc connections are not required when the unit is being operated from ac line power.
7	Input Power Connector	Provides the means of connecting the instrument through a power cord to ac line power. Line power is not required when the unit is being operated from an external 12V dc source.
8	Multipoint Input Module	Provides 10 pairs of screw-type input terminals for connecting up to 10 of the same type thermocouples. Slots are provided at the rear of the drawer for strain relief of the thermocouple bundles.

2-21. Fuse Replacement

2-22. The ac line-input section of the 2166A power supply is fuse protected. The fuse is located on the interior of the unit near the power transformer. To access the fuse, disconnect the unit from line power, remove the rear-panel retaining screw located beneath the ac line connector, and pull the case from the instrument. When replacement is necessary, use an MDL (Slo-blo) 1/8A fuse.

2-23. Overload and Open Thermocouple Indication

2-24. The front panel display, in addition to providing a measurement reading, is designed to serve as an overrange or open thermocouple indicator. When the measurement range of the input thermocouple is exceeded, or when the thermocouple inputs are open circuited, the display will blink. The blinking indication does not mean that the instrument is being exposed to a damaging input condition.

2-25. Thermocouple Connections

2-26. The 2166A is capable of monitoring the temperature of 1 of 10 thermocouple probes of the same type. The probes connect to the unit through a plug-in Multipoint Input Module as shown in Figure 2-2. Ten pairs of screw-type terminals are provided for completing the thermocouple input connections. Each set of terminals is identified by a channel number from 1 to 10 and the attached thermocouple probe assumes that channel number. A particular channel is selected and measured by setting the front panel CHANNEL Select switch to the corresponding channel number.

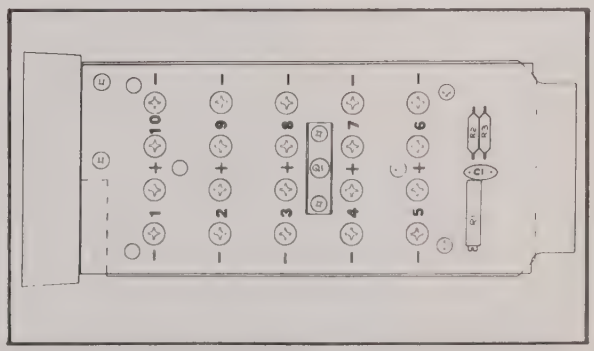

Figure 2-2. MULTIPOINT INPUT MODULE

2-27. Thermocouple Compatibility

2-28. The 2166A is designed to operate in conjunction with a selected type of thermocouple probe. A decal on the bottom of the unit identifies the compatible thermocouple type. When necessary, the 2166A can be modified in the field to accommodate any one of the following thermocouple types: J, K, T, E, R, S, B or C. Use the following procedure to change thermocouple types:

a. Refer to Table 1-1 in Section 1 of the manual and order the type select pcb which corresponds to the desired thermocouple type. These pcb's are low-cost items and can be purchased from the Manufacturer.

b. Disconnect the 2166A from line power.

c. Remove any ribbon-cable connectors that may be attached to the rear of the 2166A.

d. Disconnect the power cord from the rear of the unit.

e. Remove the rear-panel screw located just below the power input connector.

f. Pull the 2166A front panel and pcb assembly out the front of the plastic case.

g. Unplug and remove the currently installed type select pcb from the position shown in Figure 2-3, and install the new pcb in its place.

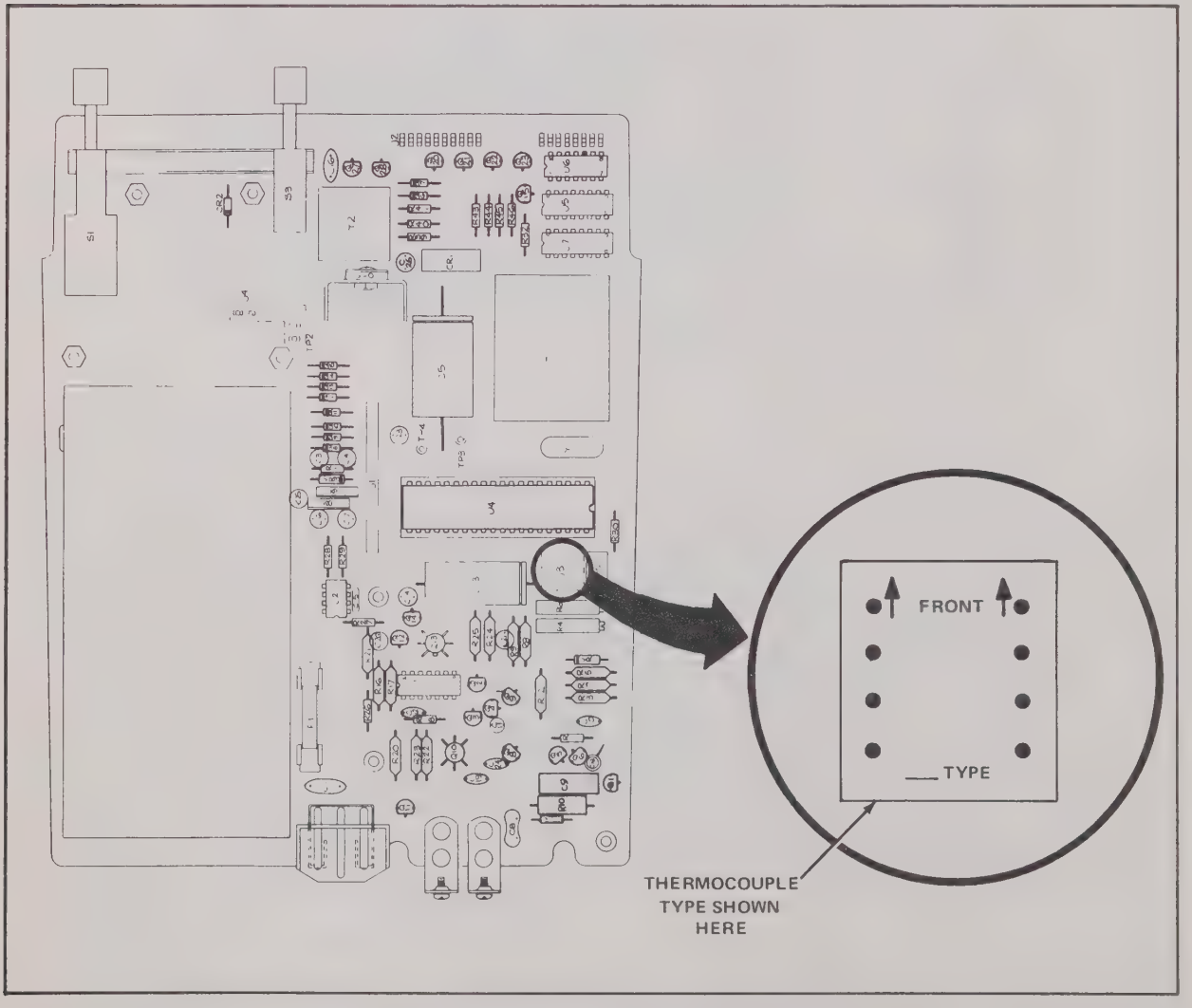

Figure 2-3. TYPE SELECT PCB, LOCATION AND INSTALLATION DETAILS

NOTE

The thermocouple type is etched on the type select pcb's. When properly installed the arrows on the pcb point toward the digital display.

h. Place a piece of tape over the thermocouple type indications on the bottom-side decal, and mark the new thermocouple type on it.

i. Connect the unit to line power, and complete the routine calibration procedure given in Section 4 (Maintenance) of this manual.

j. Install the unit in its case.

2-29. OPERATION

2-30. With reference to previous paragraphs in this section, use the following procedure to operate the 2166A:

a. Refer to the decal on the bottom of the unit and determine the compatible thermocouple type.

b. Locate the Multipoint Input Module on the rear of the unit.

c. Place your forefinger in the recess marked by the arrow and pull the drawer straight out the rear of the unit.

d. Guide the thermocouple probe connections through one of the module's rear panel openings and connect them to the desired thermocouple channel input terminals, 1 through 10. A total of 10 thermocouples (all the same type) can be simultaneously connected in this manner. Mark each probe so that it can be readily associated with its corresponding channel, 1-10.

e. Reposition the module in the 2166A and press it firmly into position.

f. Connect the unit to the appropriate line power, as defined on the bottom-decal, or to an external 12V dc source.

g. Energize the 2166A by depressing the POWER switch.

h. Determine the thermocouple probe to be monitored and set the CHANNEL Select switch to the corresponding channel.

i. Set the TEMP switch to the desired temperature scale, °C or °F.

j. Refer to Section 6 of this manual for instructions concerning the operation of the –02 and –04 Options.

k. Expose the thermocouple assigned to the selected channel to a temperature within its specified range (See bottom decal). The probe temperature will be displayed on the front panel.

Section 3
Theory of Operation

3-1. INTRODUCTION

3-2. This section of the manual contains an overall functional description followed by a circuit analysis of the 2166A. Simplified circuit diagrams and timing diagrams are included, as necessary, to supplement the text. Detailed schematics are given in Section 8 of this manual.

3-3. OVERALL FUNCTIONAL DESCRIPTION

3-4. The Model 2166A Multipoint Digital Thermometer, as shown in Figure 3-1, is a portable four-digit, manual-scan, thermocouple thermometer capable of measuring any 1 of 10 possible like-type thermocouple inputs and resolving 1°C or 1°F over a temperature range of –200 to +2328°C or –328 to 3999°F. It features switch selection of temperature scale (°C/°F) and thermocouple channel (1-10), a cold-junction compensator (to eliminate the need for an ice-bath reference junction), dual-slope integration, LSI digital control logic (includes linearization programs for J, K, T, R, S, B and C type thermocouples), a four-digit LED display, and power inputs for both ac line and external 12V dc operation.

3-5. In operation, the 2166A executes a continuous series of measurement cycles to update the temperature display. The measurement cycle is controlled entirely by an LSI digital IC, and includes three major subcycles; Auto-Zero period, Integrate period and Read period. Each subcycle controls the operation of the analog section of a dual-slope integrator which, in turn, generates a compare output to control the digital conversion performed by the LSI digital IC.

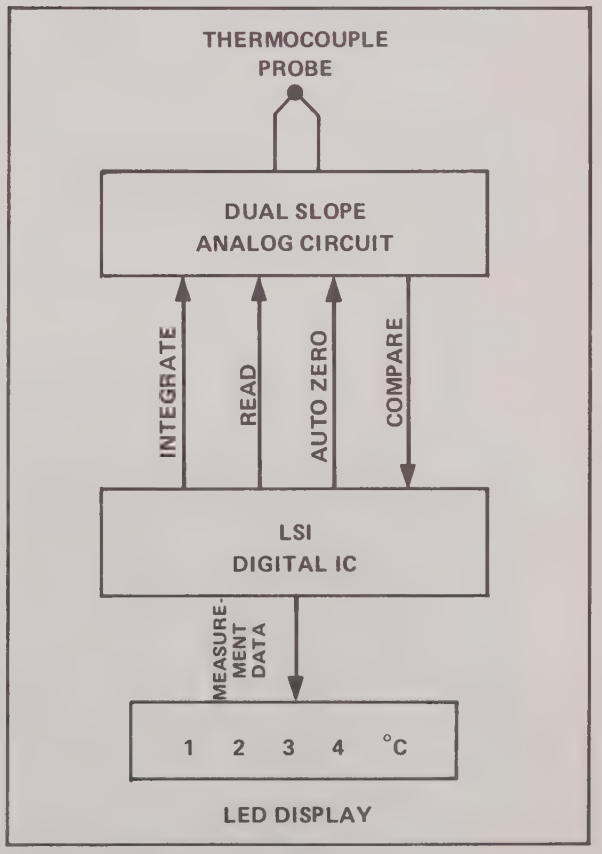

Figure 3-1. 2166A SIMPLIFIED BLOCK DIAGRAM

3-6. The configuration of the analog section of the 2166A, during each phase of the measurement cycle, is established by a combination of FET switches that are controlled by the LSI digital IC. The measurement cycle begins with the Auto-Zero period. During this period, the reference junction compensation voltage and the accumulated dc offset voltages present in the analog section are sampled and held by capacitors. These voltages are used later in the measurement cycle to cancel measurement errors introduced by offset voltages and reference junction voltage errors created at the input terminal connections. As a result, the final measurement is proportional to the thermocouple probe output voltage and does not include offset errors or reference junction voltage errors. During the Integrate period, the thermocouple input voltages (probe voltage and input terminal voltages) are applied to the integrator, and the algebraic sum of these voltages is integrated over a 100 ms period. At the end of this period, the thermocouple input voltages are removed from the integrator and the Read period is started. A reference voltage is applied to the integrator during the Read period causing the integrator capacitor to be discharged at a linear rate. When the integrator output reaches zero, a compare signal is generated to end the Read period. The duration of the Read period is translated by the LSI digital IC to provide a digital indication proportional to the thermocouple probe temperature.

3-7. CIRCUIT ANALYSIS

3-8. Circuit analysis of the 2166A is discussed in two sections; digital and analog. The digital section is covered first, and particular attention is paid to the control it exercises on the analog section. The analysis of the analog section covers the analog measurement circuitry and the 2166A power supply.

3-9. Digital Section

3-10. The digital section of the 2166A consists of an LSI digital IC, a hex buffer, a seven-segment decoder/driver and an LED display. Its function is to convert the non-linear thermocouple probe voltage, as measured by the analog section, into a linear digital display. The display provides a direct reading of probe temperature in °C or °F.

3-11. The LSI digital IC contains all of the 2166A control logic and linearizing capability, and provides the hex buffer and seven-segment decoder with the data necessary to update the LED display. The linearization of the nonlinear input signal is accomplished by selecting one of eight programs which vary the rate at which the measurement counts are accumulated. The program is selected to match a particular thermocouple type. Program selection is accomplished by a series of plug-in type select pcb's which are available as accessories.

3-12. Measurement data is continuously strobed out of the LSI digital IC in bcd, character-serial format. At the end of each measurement cycle, an update flag is raised to signify that a new reading is available. When an overload occurs, the number of accumulated counts are stored and presented, along with a blanking pulse, as output data. The blanking pulse alternately turns the display on and off to indicate the presence of an overload.

3-13. The basic measurement cycle, as shown in Figure 3-2, comprises three subcycles; a 100 ms minimum Auto-Zero period, a 100 ms Integrate period, and a variable Read period. The auto-zero period is extended to 300 ms when an overload occurs. To accommodate settling times in the analog section, a 500 us hold signal is inserted at the beginning and at the end of the Integrate period.

3-14. Analog Section

3-15. ANALOG MEASUREMENT CIRCUIT

3-16. The analog measurement circuit is shown in simplified form in Figure 3-3. It consists of a thermocouple input circuit, a reference-junction compensator, a voltage reference, a Buffer Amplifier, an Integrator, a Comparator, and a combination of FET switches. The switches are shown in their open state and are closed by the measurement cycle commands generated by the LSI digital IC. Each switch is assigned a letter designation which corresponds to a measurement cycle command shown in Figure 3-2.

3-17. The Thermocouple Input circuit consists of a 2-pole, 10 position rotaty switch connected to an R-C filter and a pair of voltage protection diodes on the thermometer pcb. The algebraic sum of the selected thermocouple prove and the input terminal voltages are passed through the rotary switch and filter, and appear at the arm of switch C.

3-18. The Reference-Junction Compensator consists of an isothermal block, 10 pairs of screw type input terminals, and a transistor temperature sensor. The isothermal block maintains a known temperature differential between the input terminals and the temperature sensing transistor. Thermocouple voltages introduced by the dissimilar metals at the input terminals vary as the isothermal block adjusts to ambient temperature. Temperature changes are sensed by the forward-biased transistor which produces a correction voltage equivalent to the thermocouple voltage created at the input terminals. Predictable characteristics of a forward-biased P-N junction allow the Reference-Junction Compensator to function over a wide temperature range. The correction voltage is matched to the thermocouple probe type by a selected Offset Resistor which is supplied on a plug-in type select pcb. The correction voltage appears at the arm of switch B1.

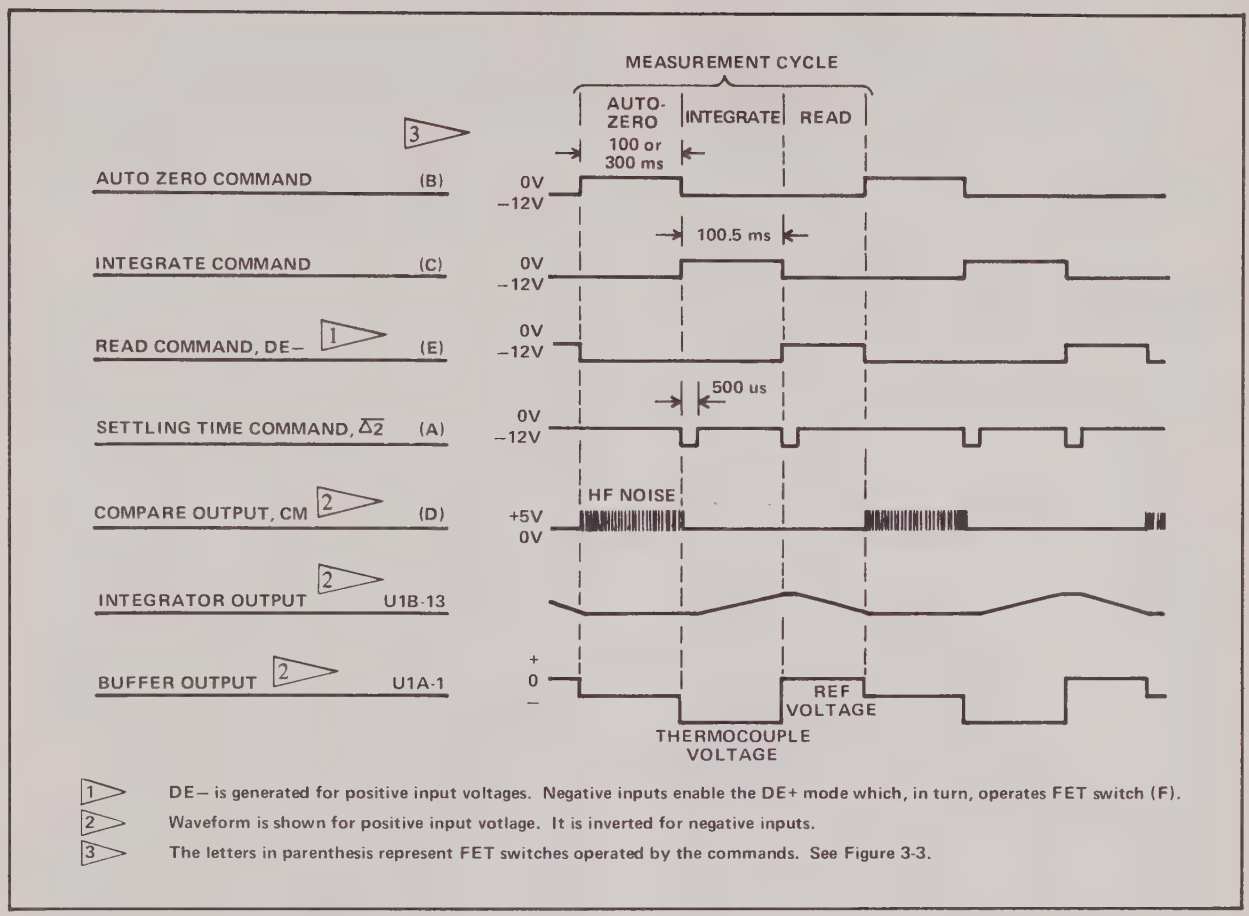
MEASUREMENT CYCLE
AUTO-ZERO
INTEGRATE
READ
100 or 300 ms
100.5 ms
500 us
AUTO ZERO COMMAND (B)
INTEGRATE COMMAND (C)
READ COMMAND, DE– (E)
SETTLING TIME COMMAND, Δ2 (A)
COMPARE OUTPUT, CM (D)
INTEGRATOR OUTPUT U1B-13
BUFFER OUTPUT U1A-1
0V
–12V
+5V
HF NOISE
REF VOLTAGE
THERMOCOUPLE VOLTAGE
1 DE– is generated for positive input voltages. Negative inputs enable the DE+ mode which, in turn, operates FET switch (F).
2 Waveform is shown for positive input votlage. It is inverted for negative inputs.
3 The letters in parenthesis represent FET switches operated by the commands. See Figure 3-3.

Figure 3-2. MEASUREMENT CYCLE WAVEFORMS

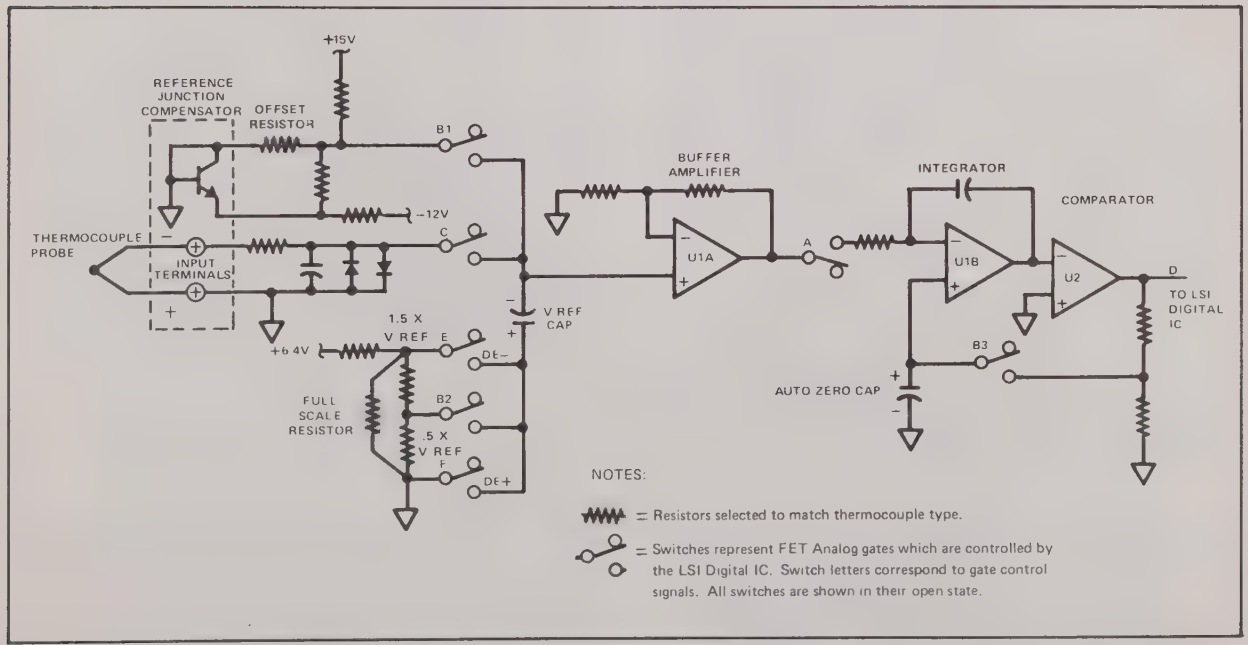

Figure 3-3. ANALOG SECTION, SIMPLIFIED CIRCUIT DIAGRAM

3-19. The voltage reference consists of a resistor divider which is supplied by an accurate 6.4V dc reference voltage. The divider is calibrated to match the thermocouple probe type by a selected resistor on the plug-in type select pcb. Two voltages are available at the divider outputs; 0.5 x V ref, and 1.5 x V ref. These voltages appear at the arms of switches B2 and E, respectively.

3-20. The Buffer, Integrator and Comparator amplifiers combine to perform the analog functions of the Integrate, Read and Auto-Zero periods. The Buffer is used to provide integrator inputs during all three periods. The Integrator integrates the Buffer output voltage during the Integrate and Read periods, and functions, in combination with the Comparator, as a closed-loop amplifier during the Auto-Zero period.

3-21. During the first phase of each measurement cycle, the analog section goes through an Auto-Zero period. During this time, three auto-zero switches (B1, B2 and B3) are closed by the Auto Zero command from the LSI digital IC. Two of the switches (B1 and B2) charge the V ref capacitor to a level equal to the algebraic sum of the 0.5 x V ref output, plus the correction voltage generated by the Reference-Junction Compensator. At the same time, the correction voltage is amplified by the Buffer Amplifier and presented through switch A to the Integrator input. The third switch (B3) connects the Integrator and Comparator in a closed loop configuration and allows the Auto-Zero capacitor to charge to a value which is proportional to the Reference-Junction-Compensator correction voltage plus the offset voltages present in the Buffer, Integrator and Comparator amplifiers. At the end of the measurement cycle switches B1, B2 and B3 are opened. The V ref capacitor and the Auto-Zero capacitor retain their charge for use later in the measurement cycle.

3-22. The Integrate period starts on the leading edge of the Integrate Command from the LSI digital IC; switch A is open and switch C is closed. The thermocouple input voltage is applied through switch C to the Buffer input. After a 500 us settling period, switch A closes and the Buffer output voltage is applied to the Integrator input for 100 ms. As the integrator capacitor charges, the Integrator drives the Comparator output to either 0 or +5V dc to indicate the polarity of the thermocouple input voltage, positive or negative, respectively. The comparator output is sent to the LSI digital IC for use during the Read period. At the end of the Integrate period, the integrator capacitor is charged to a level and polarity that is proportional to the thermocouple probe voltage and switch C returns to its open state.

3-23. The Read period starts at the end of the Integrate period and one of two Read Modes is enabled depending upon the input polarity sensed by the comparator during the Integrate period. If a positive input is sensed, a DE– Read Mode is enabled. Similarly a DE+ Read Mode is enabled when a negative input is sensed.

3-24. If the DE– Read Mode is commanded, switch A is opened and E is closed. Switch E applies a 1.5 x V ref input to the positive side of the V ref capacitor. This voltage is algebraically added to the voltage stored in the V ref capacitor during the previous Auto-Zero period (0.5 x V ref + Reference-Junction-Compensator voltage). As a result, the input to the Buffer Amplifier is a positive voltage equal to V ref plus the Reference Junction-Compensator voltage.

3-25. If the DE+ Read Mode is commanded, switch A is opened and F is closed. Switch F grounds the positive side of the V ref capacitor and causes the Buffer amplifier input to be driven to the voltage stored in the V ref capacitor during the previous Auto-Zero period (0.5 x V ref + Reference-Junction Compensator voltage). As a result, the input to the Buffer Amplifier is a negative voltage equal to 0.5 x V ref plus the Reference-Junction-Compensator voltage.

3-26. After a 500 us settling time, switch A closes and the Buffer output voltage is applied to the Integrator input. This causes the integrator capacitor to discharge at a linear rate determined by the reference voltage. The discharge continues until the integrator output voltage reaches zero volts, the level existing prior to the integrate period. This level is sensed by the Comparator which signals the LSI digital IC to terminate the A/D conversion of measurement data.

3-27. Offset voltages present during the Integrate and Read periods are cancelled out by offset voltages that were sampled and held during the Auto-Zero period. However, the Reference-Junction-Compensator voltage (also sampled and held during Auto Zero) is added to the integrator voltage during the Integrate period. As a result, the displayed temperature is equal to the thermocouple probe temperature.

3-28. POWER SUPPLY

3-29. The 2166A power supply consists of a power transformer, fuse, power input connector, a dc-to-dc converter, and associated regulating circuits. The function of the power supply is to provide the unit with the necessary operating voltages during both external battery (12V dc) and ac line operation. Operating voltages include: +5, +6.8, +15 and –12V dc. All voltages except the +5V dc is regulated. During line operation, an additional +5V ac (rms) source is available for use by ground-isolated output options (–02 and –04).

NOTE

The –02 and –04 output options are functional only when the unit is operated from the ac line.

3-30. The dc-to-dc converter is energized by a +9.6V dc input which is derived from either the power transformer during line operation, or the external dc source. Conventional regulating and isolating techniques produce +6.8, +15, –12 and +5V dc operating voltages at the dc-to-dc converter output.

Section 4
Maintenance

WARNING!

THESE SERVICING INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING OTHER THAN THAT CONTAINED IN THE OPERATING INSTRUCTIONS UNLESS YOU ARE QUALIFIED TO DO SO.

4-1. INTRODUCTION

4-2. This section of the manual provides information about warranty, factory service, maintenance, performance testing, routine recalibration and recalibration after repair. The performance test is recommended when the instrument is received and later as a preventive maintenance tool or for testing after repair. The test verifies performance at several temperatures within the range of a given thermocouple type. Specifications are provided both for annual and for a more precise 90-day performance-testing cycle.

4-3. SERVICE INFORMATION

4-4. The instrument is warranted for a period of one year upon delivery to the original purchaser.

4-5. Factory authorized calibration and service for each product is available.

4-6. GENERAL MAINTENANCE

4-7. Access Information

4-8. Access to the Multipoint Input Module does not require removal of the instrument from its case.

a. The Multipoint Input Module is a plug-in pcb assembly which is removable from the rear of the 2166A. A finger-slot marked PULL allows the module to be grasped and pulled from the case. Internal connector pressure holds the module in place.

b. The Main PCB Assemblies may be accessed in the following manner:

1. Set the POWER switch to OFF and disconnect the ac and 12V dc power cords from the unit.
2. If the thermocouple wires are connected to the Multipoint Input Module, remove the module.
3. Remove the phillips-head screw located in the center of the rear panel.

4. Pull the instrument from the front of the case.

4-9. Cleaning

4-10. Clean the instrument periodically to remove dust, grease and other contamination. Use the following procedure:

CAUTION!

Do not use aromatic hydrocarbons or chlorinated solvents for cleaning. They will react with plastic materials used in manufacture of the instrument.

a. Clean the front panel and case with a soft cloth dampened with a mild solution of detergent and water.

b. Clean the surface of the pcb using clean dry air at low pressure (≤20 psi). If grease is encountered, spray with Freon T. F. Degreaser or anhydrous alcohol and remove grime with clean dry air at low pressure.

4-11. Fuse Replacement

WARNING!

DISCONNECT THE UNIT FROM LINE POWER BEFORE ATTEMPTING FUSE REPLACEMENT.

4-12. The input power fuse is located on the interior of the unit near the ac line connector. If replacement is necessary, use an MDL (Slo-blo) 1/8A fuse.

4-13. Service Tools

4-14. No special tools are required for maintenance or repair.

4-15. PERFORMANCE TEST

4-16. Table 4-1 lists the equipment required for performance testing and recalibration. If the recommended model of test equipment is not available, a substitute that meets the minimum use specifications may be used. Table 4-2 outlines the Performance Test. A Performance Checklist at the end of this section may be reproduced or removed to provide a written record of results. The Performance Test verifies instrument performance to specifications for initial acceptance or for maintenance. (Periodic recalibration requires the calibration procedure beginning in

Table 4-1. TEST EQUIPMENT REQUIREMENTS

TEST EQUIPMENT	MINIMUM USE SPECIFICATIONS	RECOMMENDED MODEL
Thermocouple Probes	Type J, K, T, E, R, S, C ANSI C96.1 (select type compatible with thermometer)	Omega TJ36 Series, Grounded Sheath
Mercury, thermometer (either °C or °F)	0.02°C Resolution ,0.05°F Resolution	Princo Model ASTM-56C Princo Model ASTM-56F
Dewar Flask/Cap	1-pint capacity	Thermos
DC Voltage Calibrator	Output Voltage: 0 to 10V Accuracy: 0.002% Resolution: 10 mV	Fluke Model 343A
Voltage Divider 100:1 or Kelvin-Varley Divider (Shunt output with 1 uf capacitor)	Ratio: 0.005%	Fluke A21-5 or Fluke 720A or Fluke 750A
Variable Line-Voltage Transformer	100, 115, 230V ac, as required, ±10%	General Radio VARIAC W5HM
Decade Resistor	Accuracy: 1% Ranges: 1K, 10K and 100K	General Radio 1434

Table 4-2. PERFORMANCE TEST DESCRIPTION

TEST	PERFORMANCE SPECIFICATIONS	TEST METHOD	PARAGRAPH NO.
Setup	– – – –	– – – –	4-17
Overload and Open Input Test	The display flashes to indicate both over range input voltages and open input terminals.	An over range voltage is applied to the thermocouple input terminals, and the input terminals are open circuited.	4-19
Line Voltage Regulation	Satisfactory performance with any line voltage within ±10% of nominal; 100, 115 or 230V ac.	The display is monitored during the accuracy test as the line voltage is varied.	4-21
Accuracy Test	Temperature Accuracy as stated in Table 4-3	Known input voltages are substituted for the thermocouple inputs. Cardinal-point checks ensure accuracy over the entire temperature range.	4-23
Internal Temperature Rise	<8°C (14.4°F) above ambient	The thermocouple input terminals are shorted and the temperature of the reference junction is displayed.	4-25

paragraph 4-27). If the thermometer fails to meet specifications, it requires recalibration or repair. Review Table 4-2, then continue.

NOTE

The Performance Test should be conducted at an ambient temperature of 25 ± 2° C (77 ± 3.6° F).

4-17. Set-Up Procedure

4-18. The following steps prepare for performance testing:

a. Remove the thermometer from its case.

b. Locate the RJD switch on the display pcb (See Figure 4-1) and set it to the RJD position. (This defeats the reference-junction circuitry.)

c. Connect a voltage divider to a dc voltage calibrator as in Figure 4-2. (See Table 4-1 for specifications.)

d. Connect the voltage-divider output to a pair of thermometer input terminals. Any pair may be used. Match polarity.

e. Connect a variable line-power transformer to line power and adjust the output to the nominal line voltage at which the thermometer is designed to operate; 100, 115, or 230V ac.

f. Connect a power cord between the transformer output and the thermometer ac line connector.

g. Set the thermometer front-panel controls as follows:

1. POWER switch to ON.
2. TEMP switch to °F or °C.
3. CHANNEL Select switch to the channel used in d. above.

h. Set the calibrator to zero volts output, 10 volt range, and turn it on.

4-19. Overload and Open Input

4-20. The following procedure tests the thermometer overload and open-circuit detectors:

a. Set the calibrator output to 10V dc. The thermometer display should begin to flash. While the display is lit, it should read the high end of the temperature range assigned to the compatible thermocouple type:

J	=	1432°F	or	778°C
K	=	2472°F	or	1356°C
T	=	752°F	or	400°C
E	=	1832°F	or	1000°C
R	=	3232°F	or	1778°C
S	=	3232°F	or	1778°C
B	=	3352°F	or	1844°C
C	=	3999°F	or	2328°C

b. Set the calibrator output to 0V dc.

c. Remove the input connections at the thermometer thermocouple input terminals. The display should begin to flash and read the low end of the temperature range except B which will display 32° F or 0° C. (Note: The low end of the B range is +533° C or +992° F).

J	=	-328°F	or	-200°C
K	=	-328°F	or	-200°C
T	=	-328°F	or	-200°C
E	=	-328°F	or	-200°C
R	=	32°F	or	0°C
S	=	32°F	or	0°C
B	=	32°F	or	0°C
C	=	32°F	or	0°C

d. This completes the overload and Open-Input test.

4-21. Line Voltage Regulation

4-22. Line voltage regulation is tested in conjunction with the accuracy test given in the following paragraphs. As the accuracy test is executed, vary the line voltage ± 10% with the variable line-power transformer to ensure the proper operation within the line-voltage limits.

4-23. Accuracy Test

4-24. The following procedure tests the accuracy of the thermometer:

a. Connect the voltage-divider leads to the same pair of thermocouple input terminals previously selected in 4-18 d. and g. above.

b. Refer to Table 4-3 and select the group of values that correspond to the thermocouple type used with the thermometer.

c. Sequentially, set the calibrator to obtain each of the divider output voltages listed within the selected group, and check the thermometer display against the appropriate display limits; 90-day or 1-year. Vary the ac voltage over the specified ± 10% operating range. Check to see that the thermometer is still reading within accuracy specifications.

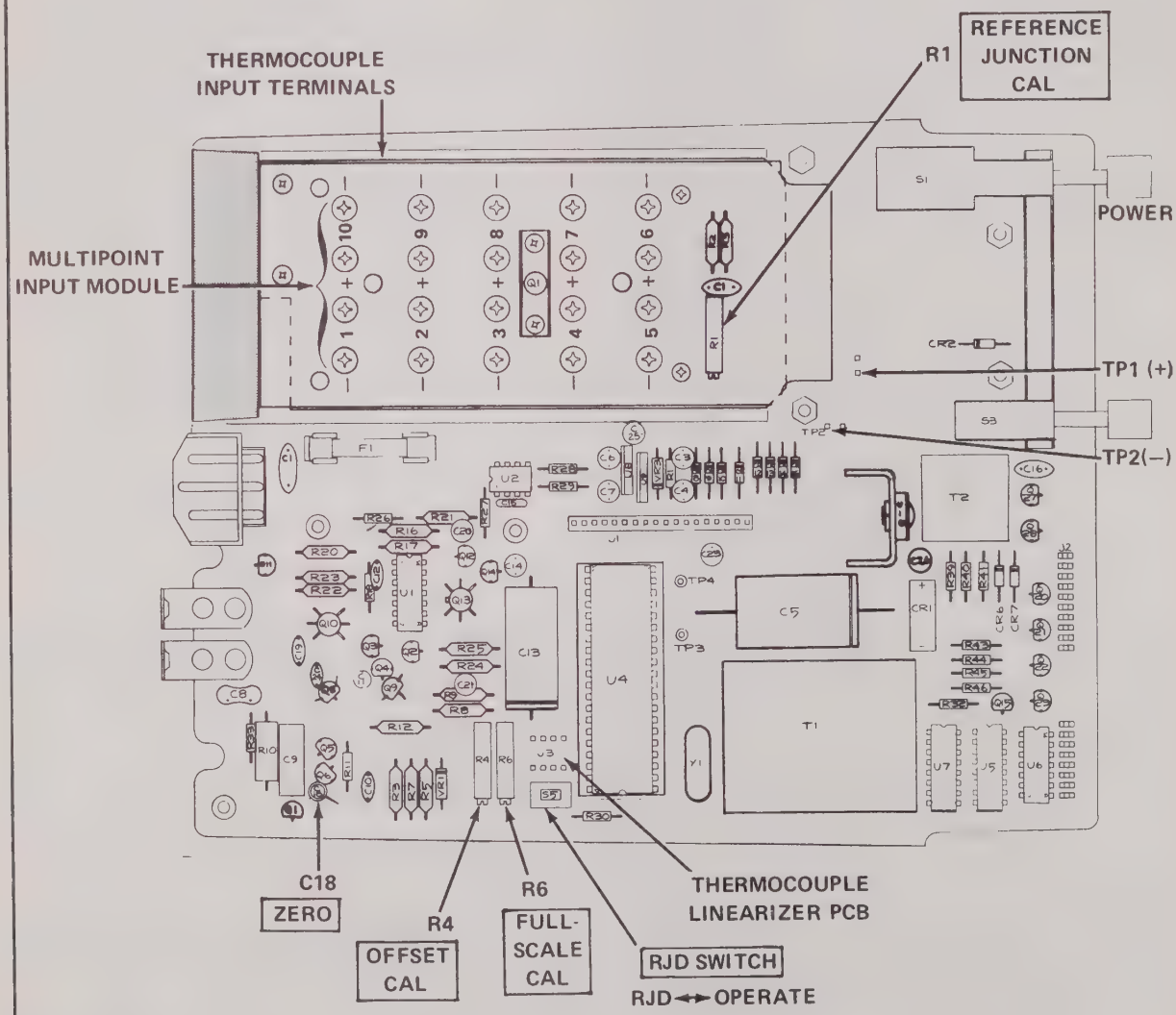

Figure 4-1. ADJUSTMENT AND TEST POINT LOCATIONS

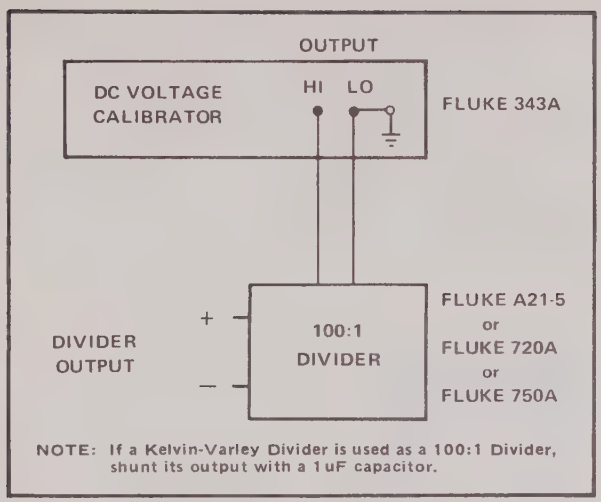

Figure 4-2. VOLTAGE DIVIDER–CALIBRATOR CONNECTION

d. Remove the voltage divider from the thermometer input.

e. Set the RJD switch to the operate position.

f. Install the thermometer in its case.

g. Connect a thermocouple of the appropriate type to the same thermocouple input terminals previously selected. Match polarity. J, K, T and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S, and C color coding.

h. Place the thermocouple in a room-temperature lag bath. (See Figure 4-3 for an illustration of lag-bath construction. Two holes should be drilled in the thermos lid to provide a snug fit for the mercury thermometer and thermocouple probe.)

Table 4-3. TEMPERATURE ACCURACY

TYPE	°F			°C		
	DIVIDER OUTPUT (mV dc)	DISPLAY LIMITS		DIVIDER OUTPUT (mV dc)	DISPLAY LIMITS	
		90 DAY	1 YEAR		90 DAY	1 YEAR
J	42.640	1390.5 to 1393.5	1389.5 to 1394.5	42.640	754.6 to 756.6	754.1 to 757.1
	2.288	110.5 to 113.5	109.5 to 114.5	2.288	43.4 to 45.4	42.9 to 46.9
	–1.643	–30 to –26	–31 to –25	–2.175	–45.9 to –42.9	–46.9 to –42.9
	–7.634	–310 to –306	–311 to –305	–7.344	–179.3 to –176.3	–179.3 to –176.3
K	52.789	2389.5 to 2394.5	2388.5 to 2395.5	49.638	1220.7 to 1223.7	1220.2 to 1224.2
	2.709	149.5 to 154.5	148.5 to 155.5	6.363	154.1 to 157.1	153.6 to 157.6
	–1.691	–50.5 to –45.5	–51 to –45	–1.691	–45.9 to –42.9	–46.4 to –42.4
	–5.713	–310.5 to –305.5	–311 to –305	–5.510	–179.3 to –176.3	–179.8 to –175.8
T	20.188	730.5 to 733.5	730 to 734	19.497	376.8 to 378.8	376.8 to 378.8
	0.879	70.5 to 73.5	70 to 74	0.8789	21.2 to 23.2	21.2 to 23.2
	–1.240	–30.5 to –25.5	–31.5 to –24.5	–2.009	–57.1 to –54.1	57.6 to – 53.6
	–5.421	–310.5 to –305.5	–311.5 to –304.5	–5.221	–179.3 to –176.3	–179.8 to –175.8
E	74.694	1790 to 1794	1789 to 1795	74.694	976.3 to 979.3	975.8 to 979.8
	2.694	110 to 114	109 to 115	2.694	42.9 to 45.9	42.4 to 46.4
	–1.897	–30.5 to –25.5	–31.5 to –24.5	–3.080	–57.1 to –54.1	–57.6 to –53.6
	–8.529	–310.5 to –305.5	–311.5 to –304.5	–8.209	–179.3 to –176.3	–179.8 to –175.8
R	20.951	3188 to 3196	3187 to 3197	20.951	1753.1 to 1758.1	1752.6 to 1758.6
	0.259	108 to 116	107 to 117	0.259	41.9 to 46.9	41.4 to 47.4
S	18.321	3148 to 3156	3147 to 3157	17.295	1642.4 to 1646.4	1641.4 to 1647.4
	0.262	108 to 116	107 to 117	0.262	42.4 to 46.4	41.4 to 47.4
B	13.585	3268 to 3276	3267.5 to 3276.5	13.585	1798 to 1802	1797.5 to 1802.5
	1.535	1028 to 1036	1027.5 to 1034.5	1.661	575.8 to 579.8	575.3 to 580.3
C	35.875	3976.5 to 3987.5	3976.5 to 3988.5	35.875	2191 to 2197	2191 to 2197
	1.276	186.5 to 197.5	186.5 to 198.5	.614	41 to 47	41 to 47

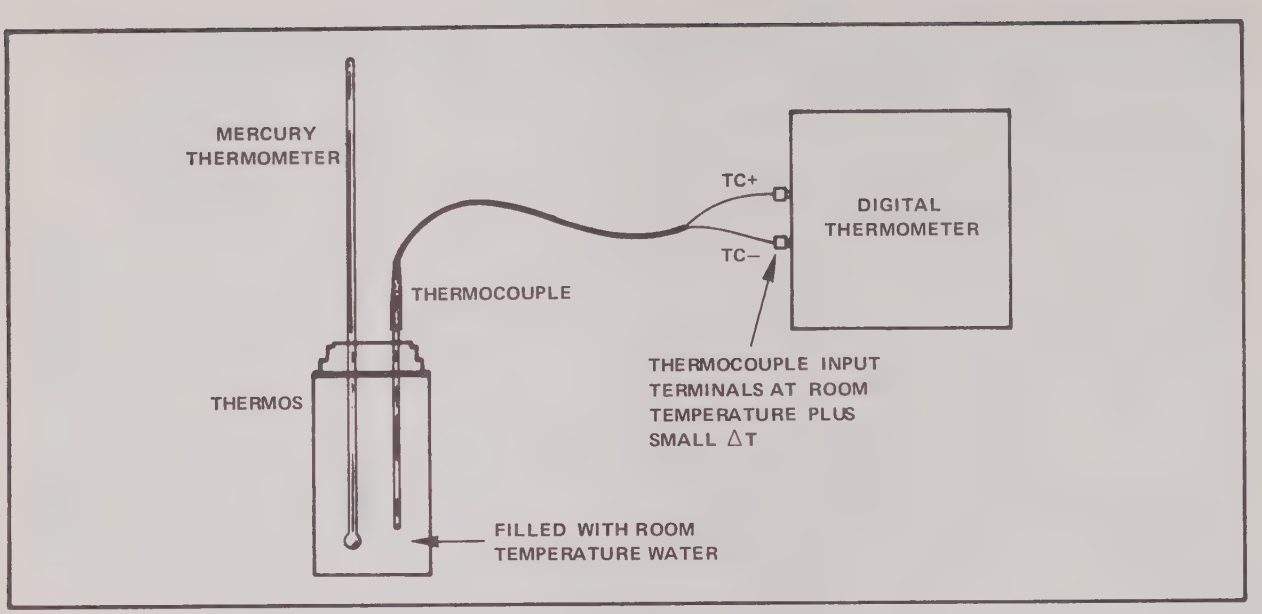

Figure 4-3. ROOM TEMPERATURE LAG BATH

i. Refer to Table 4-4. Determine if the thermometer display is within the specified range of the lag-bath temperature reading.

NOTE

Allow sufficient time for the mercury thermometer to come to a stable lag-bath temperature reading.

Table 4-4. REFERENCE-JUNCTION ACCURACY LIMITS

TYPE THERMOCOUPLE	°F	°C
J	±1.5°	±1.5°
K	±2.0°	±1.5°
T	±1.5°	±1.5°
E	±1.5°	±1.5°
R	±2.5°	±2.0°
S	±2.5°	±2.0°
C	±4.5°	±3.0°
The thermometer should read within the above limits for either the 90-day or 1-year check.		

j. This completes the accuracy test portion of the Performance Test.

4-25. Internal Temperature Rise

4-26. The following procedure measures the thermometer's internal temperature as sensed by the reference junction:

a. Connect a copper wire between the thermocouple input terminals (in place of the thermocouple leads used in the preceding test).

NOTE

This procedure assumes that the thermometer has been energized for at least 30 minutes.

b. Monitor the ambient temperature (room temperature) using a mercury thermometer near the back of the digital thermometer.

c. The digital thermometer will display the temperature of the internal reference junction. This temperature should not exceed the ambient temperature by more than 8° C (14.4° F).

d. Remove the short from the thermocouple input terminals.

e. This completes the test for internal temperature rise.

4-27. CALIBRATION

4-28. The thermometer should be calibrated every year or every 90 days, depending on the desired accuracy. Calibration should be performed also after the thermometer has been repaired or after the thermocouple linearizer (type-select) pcb has been changed.

4-29. Calibration of either the °F or °C scale, ensures the accuracy of both scales. Either scale can be verified after calibration by executing the accuracy portion of the Performance Test.

4-30. Interpolation of calibration setting for the °F scale is not necessary to obtain the specified performance accu-

racy. However, the °C scale requires interpolation of the calibration setting in order to obtain the specified performance. The following examples illustrate the difference.

4-31. °F example: For a K-type thermocouple, a voltage divider output of 52.789 mV is applied to the thermometer input. (See Table 4-5.) It is necessary only to set the calibration potentiometer to any setting that results in a digital display of 2392° F.

Table 4-5. FULL SCALE CALIBRATION

PROBE TYPE	°F		°C	
	DIVIDER OUTPUT (mV dc)	DISPLAY READING	DIVIDER OUTPUT (mV dc)	DISPLAY READING
J	+42.640	1392°F	+42.640	755.6°C
K	+52.789	2392°F	+49.638	1222.2°C
T	+20.188	732°F	+19.497	377.8°C
E	+74.694	1792°F	+74.694	977.8°C
R	+20.951	3192°F	+20.951	1755.6°C
S	+18.321	3152°F	+17.295	1644.4°C
B	+13.585	3272°F	+13.585	1800.0°C
C	+35.875	3982°F	+35.875	2194.4°C

4-32. °C Example: Calibration in °C is slightly more involved. For a K-type thermocouple, Table 4-5 shows that 49.638 mV are to be applied to the thermocouple input terminals. In order to calibrate to a required ± .25° C of the specified 1222.2° C, first adjust the potentiometer for a display flicker from 1221 to 1222. This locates the 1221.5° C position of the potentiometer. (The thermometer internally "rounds up" .5, .6, .7, .8, and .9 values, and drops .1, .2, .3 and .4). Next, count the number of turns, X, of the potentiometer to reach a display flicker from 1222 to 1223. This locates the 1222.5° C position of the potentiometer. Turn the potentiometer back .3X turns to locate the 1222.2° C position of the pot.

4-33. B-type thermocouple calibration is different than that for other thermocouple types. A B-type thermocouple has no output at room temperature so does not require offset and reference-junction compensation for the equivalent thermocouple formed at the instrument input terminals. Therefore, to calibrate a B-type thermocouple, leave the RJD switch set to the operate position and execute only paragraphs 4-34, 4-35, 4-36 and 4-37, of the Calibration procedure; then reassemble the digital thermometer.

4-34. Calibration Procedure

4-35. SET-UP FOR CALIBRATION

a. Complete the equipment connections shown in Figure 4-2, by doing the following:

1. Connect the 100:1 divider specified in Table 4-1.

2. Apply power to the calibrator and turn it on. Allow sufficient warm-up time to assure calibration-output-voltage accuracy.

b. Remove the thermometer from its case. See paragraph 4-7.

c. Locate the RJD switch on the main pcb. Set it to to the RJD position. (This defeats the reference-junction circuitry.)

d. Connect the voltage-divider output to a pair of thermocouple input terminals.

e. Connect a short length of copper wire between the thermocouple input terminals.

f. Set the thermometer front panel controls as follows:

1. POWER switch to ON.

2. TEMP switch to °F or °C.

3. CHANNEL Select switch to the channel used in d. above.

4-36. ZERO ADJUSTMENT

a. Adjust C18 to obtain a steady or flashing 0 or -0 for the Celsius scale, or to obtain a steady 32 for the Fahrenheit scale.

4-37. FULL SCALE ADJUSTMENT

a. Determine the thermocouple compatible with the thermometer. The decal on the bottom of the thermocouple case or the markings on the plug-in linearizer (type-select) pcb indicate the thermocouple type. (See Figure 4-1.)

b. Remove the short and connect the 100:1 divider output to the thermocouple input terminals. Match polarity.

c. Refer to Table 4-5 and set the calibrator output to obtain the voltage divider output specified for the compatible thermocouple type, for the degree scale being used.

d. Adjust the FULL-SCALE CAL potentiometer, R6 (Figure 4-1), to obtain the temperature display specified in Table 4-5.

e. This completes the calibration procedure for B-type thermocouples only.

4-38. OFFSET ADJUSTMENT

a. Set the RJD switch to the operate position.

b. Remove the divider leads from the thermocouple input terminals.

c. Short the thermocouple input terminals with a small piece of copper wire.

d. Remove the 100:1 divider from the calibrator output.

e. Set the calibrator to the 10V dc range.

f. Adjust the calibrator output to .5785V dc.

CAUTION

Be sure the voltage output of the calibrator is .5785V dc before proceeding to the next step. Improper voltage could damage the digital thermometer. Do not use the divider to obtain .5785V dc because the output impedance will create an error.

g. Connect the positive lead from the calibrator to the positive thermocouple input terminal of the same pair previously selected.

h. Connect the negative lead from the calibrator to Test Point 2. (TP2(–) in Figure 4-1).

i. Adjust the OFFSET CAL potentiometer, R4, for a temperature display of 77° F or 25° C ± ¼° C. (See Paragraph 4-30 on interpolation.)

j. Remove the calibrator output from the thermocouple input terminal used and TP2(–).

k. Remove the short at the thermocouple input terminals.

l. If the thermometer is being calibrated on a routine calibration cycle, or because of thermocouple type-change, this completes calibration. Reassemble the thermometer.

m. If the thermometer is being recalibrated because of repair or if reference-junction adjustment is desired, proceed with paragraph 4-39.

n. Extra multipoint pcb assemblies can be purchased for the 2166A. Reference junctions for these units are adjusted at the factory. If the extra multipoint pcb assembly has been repaired or if there is other reason to adjust its reference junction, install the multipoint pcb in a calibrated 2166A and proceed with paragraph 4-39.

4-39. REFERENCE-JUNCTION ADJUSTMENT

a. Connect a compatible thermocouple probe to the same input terminals selected previously by the CHANNEL select switch. Match polarity. J, K, T, and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S, and C color coding.

b. Place the thermocouple in a room-temperature lag bath. (See Figure 4-3 for an illustration of lag-bath construction.)

c. Use an accurate mercury thermometer to monitor the temperature of the lag-bath. (See Table 4-1.)

d. Adjust the REFERENCE-JUNCTION CAL potentiometer, R1, to obtain a display that agrees with the lag-bath temperature.

NOTE

When adjusting the reference junction of a multipoint pcb assembly that was purchased as an option, it may not be possible to obtain a display that agrees exactly with the lag-bath temperature. In such a case, set the reference-junction potentiometer, R1, for a display reading as close to lag-bath temperature as possible. The difference will be small and within the calibration accuracy specified for the instrument.

e. Remove the thermocouple and reassemble the digital thermometer.

4-40. REFERENCE-JUNCTION BIAS-RESISTOR SELECTION

4-41. If the reference-junction transistor Q1 is replaced, then the reference-junction bias resistor R3 must also be replaced. This is a selected resitor which must be matched to Q1. To select the resistor:

a. Complete the calibration paragraphs 4-35 through 4-38.

b. Connect a compatible thermocouple probe to the input terminals. Match polarity. J, K, T and E thermocouples have a red wire for the negative lead. Refer to the manufacturer for R, S and C color coding.

c. Center the reference-junction pot R1.

d. Connect a decade resistance box that has ranges including 1K, 10K, and 100K, in place of the reference-junction bias resistor R3. (See Table 4-1.)

e. Place the thermocouple in a room-temperature lag bath. (See Table 4-3 for an illustration of lag-bath construction.)

f. Use an accurate mercury thermometer to monitor the temperature of the lag bath. (See Table 4-1.)

g. Adjust the decade resistance box for the value from Table 4-6 that causes the thermometer to read closest to lag-bath temperature. This will be the value of the reference-junction bias resistor R3.

h. Disconnect the decade box and install the selected R3.

i. Adjust the reference junction potentiometer so that the thermometer reading matches the lag-bath temperature.

j. Remove the thermocouple and reassemble the digital thermometer.

k. This completes the selection of R3. This also completes the calibration of the reference junction.

Table 4-6. BIAS RESISTOR VALUES

VALUE	STOCK NUMBER	VALUE	STOCK NUMBER
49.9K	268821	90.9K	223537
52.3K	237248	100K	248807
54.9K	271353	110K	234708
57.6K	289116	124K	288407
60.4K	291419	140K	289439
63.4K	235382	162K	375998
68.1K	236828	191K	375923
73.2K	237222	237K	288373
78.7K	289058	309K	235283
84.5K	229492	562K	235358

4-42. CALIBRATION TECHNIQUES

4-43. Calibration of the reference junction (R1) can be performed using any type of thermocouple except B-type. Once the reference junction has been calibrated for one type of thermocouple, it will be in calibration for use with any other thermocouple type. (Type B thermocouples do not use the reference junction due to their low output levels at room temperature.) Therefore, a calibration facility that maintains several digital thermometers which are configured for different thermocouple types, requires only one thermocouple probe and its corresponding linearizer (type-select) pcb in order to calibrate the reference junction of all of the instruments. A K-type thermocouple and linearizer pcb are recommended. The following procedure illustrates:

a. Calibrate the repaired thermometer with the K-type thermocouple and K-type linearizer pcb installed. Follow paragraphs 4-35 through 4-39. This calibrates the reference junction.

b. Change the thermometer to another type of thermocouple by changing the linearizer pcb and repeating paragraphs 4-35 through paragraph 4-38 only. These paragraphs do not require the actual thermocouple probe, but accomplish full-scale calibration for the non-K-type probe without disturbing the reference-junction calibration just set in a. above.

c. This technique is especially useful in the repair of an instrument that is normally used with a C-type thermocouple. C types are expensive, the wire is brittle and the accuracy is relatively poor. The calibration facility can use the above technique rather than to stock C-type probes.

4-44. Thermocouple Accuracy Relating to the Reference-Junction Calibration Technique

4-45. The thermocouples specified in the list of calibration equipment meet specifications of ANSI Standard C96.1. The specifications for these probes can be as much as 4°F absolute error at or near room temperature. The first conclusion is that those probes could produce a calibration error of ±4° F when used for calibrating the reference junction. This is an erroneous conclusion. Figure 4-3 illustrates the set-up for calibration. Figure 4-4A illustrates the reference-junction compensation circuity and Figure 4-4B illustrates the equivalent thermocouple circuit formed by the connection of the thermocouple to the input of the instrument. Note that in Figure 4-4B, the two thermocouple junctions formed at the input of the instrument (plus-thermocouple wire (+TC) to the plus input terminal and the minus thermocouple wire (–TC) to the minus input terminal) can be represented as a single junction of +TC to –TC whose temperature is that of the input terminals of the instrument. The reference-junction circuitry senses the terminal temperature and generates a voltage that is equal to the voltage generated by the equivalent thermocouple formed at the input terminals referenced to ice point (See Figure 4-4). For example, suppose the input terminals of the instrument and the attached probe are at the same temperature of 25° C. Since the thermocouple output voltage is proportional to the temperature between the two junctions, the output is zero volts. The reference-junction circuitry supplies a compensating voltage to the instrument

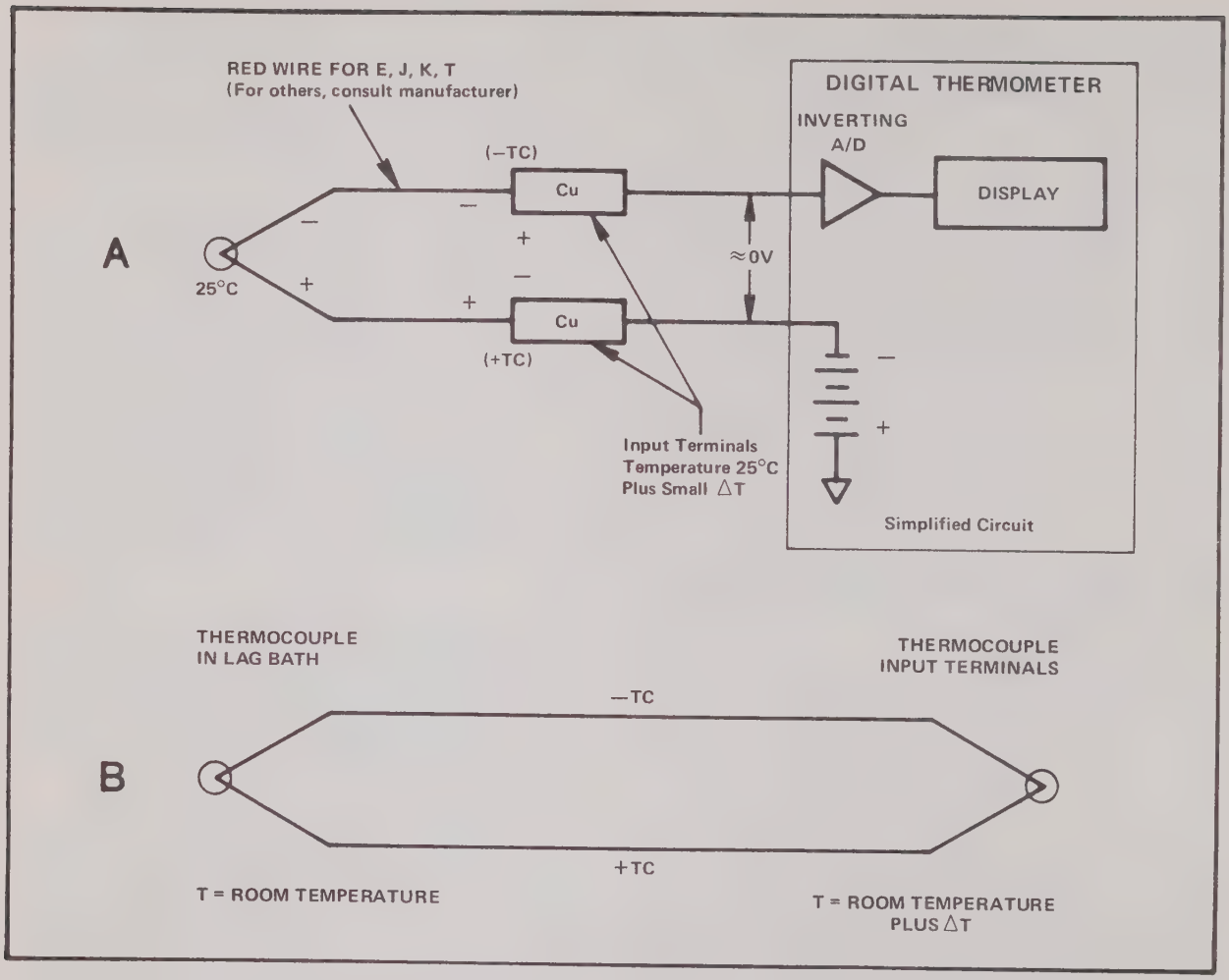

Figure 4-4. REFERENCE-JUNCTION COMPENSATION CIRCUITRY

such that the instrument will read 25° C. When calibrating the reference junction using the lag-bath technique, the reference is adjusted so that the instrument reads the lag-bath temperature. In using the lag-bath technique, there is only a small temperature difference, ΔT, between the thermocouple junction in the probe and the equivalent thermocouple junction formed at the input terminals of the instrument. The voltage output across the thermocouple circuit is proportional to the temperature difference, ΔT, between the two junctions. Hence, since ΔT is small, there is a small input voltage applied to the input of the instrument. This small input voltage will represent ΔT accurately to within less than .1° F. Therefore, when the reference junction is calibrated so that the instrument reads lag-bath temperature, the error introduced by the thermocouple will be less than .1° F.

4-46. Over-all Accuracy

4-47. The instrument will read very accurately around room temperature (See paragraph 4-44) but as the measured temperature increases or decreases from room temperature, the amount of thermocouple output deviation from NBS Standard 125, becomes the limiting factor in the accuracy of the instrument. If the thermocouple is in error by +4° F, at 900° F the display will be +4° F higher than if the thermocouple conformed perfectly to NBS Standard 125. Error specifications for the instrument do not include thermocouple probe inaccuracies. Those errors must be added to the instrument error in order to obtain an over-all accuracy figure.

4-48. TROUBLE SHOOTING

4-49. A troubleshooting guide for the thermometer is given in Table 4-7. The guide is a simplified decision table and is recommended for use in isolating a problem to a functional circuit group. Details necessary to troubleshoot a fault in a functional circuit group can be derived from Section 3 Theory of Operation and Section 8 Schematic Diagrams.

Table 4-7. TROUBLESHOOTING GUIDE

STEP	INSTRUCTION	IF YES GO TO	IF NO GO TO	GO TO
1	Energize the unit and connect a short across the thermocouple input terminals.			2
2	Does the display light?	16	3	
3	Is the power fuse blown?	4	5	
4	Replace fuse.			2
5	Are all power supply voltages present; +5, +6.8, +15 and −12V dc?	7	6	
6	Repair power supply.			2
7	Are Strobe Out pulses present at pins 9, 10, 11 and 12 of U4. (Use logic common as reference.)?	10	8	
8	Is crystal operating?	10	9	
9	Replace crystal.			2
10	Are display drivers functioning?	13	11	
11	Is output data present at pins 4, 5, 6 and 7 of U4?	12	13	
12	Replace display drivers as necessary.			2
13	Are $\overline{\Delta 2}$, AZ, INT, DE+ or DE−, and CM present at U4?	14	15	
14	Display PCB defective. Repair as necessary.			2
15	U4 is defective. Replace.			2
16	Does display read approximate ambient temperature?	21	17	
17	Refer to Section 3 of this manual and use a scope to check for the presence of the waveforms shown in Figure 3-2.			18
18	Are all waveforms correct?	20	19	
19	Perform the necessary repairs to the analog circuit.			17
20	Calibrate the thermometer.			21
21	End. Thermometer is functional.			

PERFORMANCE TEST CHECKLIST

Model 2166A Digital Thermometer

Serial No. _____

Tested By _____

Date _____

Line Voltage Regulation . . . . . Passed ( ) Failed ( )

Accuracy Test . . . . . See Verification Tables

°F Verification Table (Temperature Accuracy)

PROBE TYPE	NOMINAL TEMPERATURE °F	90 DAY			1 YEAR		
		MIN.	ACTUAL	MAX.	MIN.	ACTUAL	MAX.
J	1392	1390.5		1393.5	1389.5		1394.5
	112	110.5		113.5	109.5		114.5
	–28	–30		–26	–31		–25
	–308	–310		–306	–311		–305
K	2392	2389.5		2394.5	2388.5		2395.5
	152	149.5		154.5	148.5		155.5
	–48	–50.5		–45.5	–51		–45
	–308	–310.5		–305.5	–311		–305
T	732	730.5		733.5	730		734
	72	70.5		73.5	70		74
	–28	–30.5		–25.5	–31.5		–24.5
	–308	–310.5		–305.5	–311.5		–304.5
E	1792	1790		1794	1789		1795
	112	110		114	109		115
	–28	–30.5		–25.5	–31.5		–24.5
	–308	–310.5		–305.5	–311.5		–304.5
R	3192	3188		3196	3187		3197
	112	108		116	107		117
S	3152	3148		3156	3147		3157
	112	108		116	107		117
B	3272	3268		3276	3267.5		3276.5
	1032	1028		1036	1027.5		1034.5
C	3982	3976.5		3987.5	3976.5		3988.5
	192	186.5		197.5	186.5		198.5

PERFORMANCE TEST CHECKLIST, Cont.

Overload

Overrange . . . . . Passed ( ) Failed ( )

Open Circuit . . . . . Passed ( ) Failed ( )

Internal Temperature Rise . . . . . <8°C (14.4°F) above ambient

°C Verification Table (Temperature Accuracy)

PROBE TYPE	NOMINAL TEMPERATURE °C	90 DAY			1 YEAR		
		MIN.	ACTUAL	MAX.	MIN.	ACTUAL	MAX.
J	755.4	754.6		756.6	754.1		757.1
	44.4	43.4		45.4	42.9		46.9
	–44.4	–45.9		–42.9	–46.9		–42.9
	177.8	–179.3		–176.3	–179.3		–176.3
K	1222.2	1220.7		1223.7	1220.2		1224.2
	155.6	154.1		157.1	153.6		157.6
	–44.4	–45.9		–42.9	–46.4		–42.4
	–177.8	–179.3		–176.3	–179.8		–175.8
T	377.8	376.8		378.8	376.8		378.8
	22.2	21.2		23.2	21.2		23.2
	–55.6	–57.1		–54.1	–57.6		–53.6
	–177.8	–179.3		–176.3	–179.8		–175.8
E	977.8	976.3		979.3	975.8		979.8
	44.4	42.9		45.9	42.4		46.4
	–55.6	–57.1		–54.1	–57.6		–53.6
	–177.8	–179.3		–176.3	–179.8		–175.8
R	1755.6	1753.1		1758.1	1752.6		1758.6
	44.4	41.9		46.9	41.4		47.4
S	1644.4	1642.4		1646.4	1641.4		1647.4
	44.4	42.4		46.4	41.4		47.4
B	1800	1798		1802	1797.5		1802.5
	577.8	575.8		579.8	575.3		580.3
C	2194.4	2191		2197	2191		2197
	44.4	41		47	41		47

°F Verification Table (Reference Junction Accuracy)

Probe Type	90-Day or 1-Year	
	Deviation Error From Room-temperature Lag Bath	
	Maximum	Actual
J	±1.5°	
K	±2.0°	
T	±1.5°	
E	±1.5°	
R	±2.5°	
S	±2.5°	
C	±4.5°	

°C Verification Table (Reference-Junction Accuracy)

Probe Type	90-Day or 1-Year	
	Deviation Error From Room-temperature Lag Bath	
	Maximum	Actual
J	±1.5°	
K	±1.5°	
T	±1.5°	
E	±1.5°	
R	±2.0°	
S	±2.0°	
C	±3.0°	

Section 5

Lists of Replaceable Parts

REFERENCE DESIGNATOR	ASSEMBLY NAME/NUMBER	PART NO.	PAGE
	Digital Thermometer, Final Assembly (2166A)	———	5-3
A1	Thermometer Assembly		
	100V (2166A-4001T-2)	438549	5-5
	115V (2166A-4001T)	425595	5-5
	230V (2166A-4001T)	425595	5-5
A1A1	Thermometer PCB Assembly (2166A-4001)	425587	5-6
A1A2	Point Select PCB Assembly (2166A-4002)	425603	5-10
A2	Display PCB Assembly (2165A-4003)	443515	5-11
A3	Multipoint Input Module (2166A-4003T)	425637	5-12
A4	Type Select PCB Assembly	———	5-13

5-1. INTRODUCTION

5-2. This section contains an illustrated parts breakdown of the instrument. Components are listed alpha-numerically by assembly. Electrical components are listed by reference designation and mechanical components are listed by item number. Each listed part is shown in an accompanying illustration.

5-3. Parts lists include the following information:

a. Reference Designation or Item Number.

b. Description of each part.

c. Stock Number.

d. Federal Supply Code for Manufacturers. (See Appendix A for Code-to-Name list.)

e. Manufacturer's part Number or Type.

f. Total Quantity per assembly or component.

g. Recommended Quantity: This entry indicates the recommended number of spare parts necessary to support one to five instruments for a period of two years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for one year or more at an isolated site, it is recommended that at least one of each assembly in the instrument be stocked. In the case of optional subassemblies, plug-ins, etc. that are not always part of the instrument, or are deviations from the basic instrument mode, the REC QTY column lists the recommended quantity of the item in that particular assembly.

h. Use Code is provided to identify certain parts that have been added, deleted or modified during production of the instrument. Each part for which a use code has been assigned may be identified with a particular instrument serial number by consulting the Use Code Effectivity, paragraph 5-7.

5-4. HOW TO OBTAIN PARTS

5-5. Components may be ordered directly from the manufacturer by using the manufacturer's part number, or from the factory or by using the STOCK NUMBER. In the event the part you order has been replaced by a new or improved part, the replacement will be accompanied by an explanatory note and installation instructions, is necessary.

5-6. To ensure prompt and efficient handling of your order, include the following information.

a. Quantity

b. Stock Number

c. Description

d. Reference Designation or Item Number

e. Printed Circuit Board Part Number

f. Instrument model and Serial number

5-7. USE CODE EFFECTIVITY LIST

USE CODE	SERIAL NUMBER EFFECTIVITY
A	0123 to 50000
B	50000 and on.

Indicates MOS device which may be damaged by static discharge.

FINAL ASSEMBLY, 2166A

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	DIGITAL THERMOMETER FINAL ASSEMBLY, 2166A						
A1	Thermometer Assembly				1		
	100V ac (2166A-4001T-2)	438549	89536	438549			
	115V ac (2166A-4001T)	425595	89536	425595			
	230V ac (2166A-4001T)	425595	89536	425595			
A2	Display PCB Assembly (2165A-4003)	443515	89536	443515	1		
A3	Multipoint Input Module (2166A-4003T)	425637	89536	425637	1		
A4	Type Select PCB Assembly				1		
	One-of-eight possible type select pcb assemblies is supplied with the unit.						
	R Type Select PCB Assembly (2160A-4012)	415612	89536	415612			
	S Type Select PCB Assembly (2160A-4013)	415620	89536	415620			
	B Type Select PCB Assembly (2160A-4014)	415638	89536	415638			
	C Type Select PCB Assembly (2160A-4015)	415646	89536	415646			
	J Type Select PCB Assembly (2160A-4016)	415653	89536	415653			
	K Type Select PCB Assembly (2160A-4017)	415661	89536	415661			
	T Type Select PCB Assembly (2160A-4018)	415927	89536	415927			
	E Type Select PCB Assembly (2160A-4019)	415935	89536	415935			
1	Adhesive, die-cut	436766	89536	436766	1		
2	Case, molded plastic	432500	89536	432500	1		
3	Cord, ac line						
	100 or 115V ac	343723	89536	343723	1		
	230V ac	343780	89536	343723	1		

FINAL ASSEMBLY, 2166A, Cont.

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
4	Decal, case bottom	419200	89536	419200	1		
5	Decal, front panel	428557	89536	428557	1		
6	Decal, handle	347401	89536	347401	2		
7	Decal, switch knob	428532	89536	428532	1		
8	Feet, rubber	338632	89536	338632	2		
9	Handle, molded plastic	330092	89536	330092	1		
10	Knob, switch	438697	89536	438697	1		
11	Lens, display	419085	89536	419085	1		
12	Panel, front	417485	89536	417485	1		
13	Retainer, neoprene	352484	89536	352484	2		
14	Shield	438440	89536	438440	1		
15	Washer, handle	340505	89536	340505	2		

A1 THERMOMETER ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1	**THERMOMETER ASSEMBLY**				REF		
	100V ac (2166A-4001T-2)	438549	89536	438549			
	115V ac (2166A-4001T)	425595	89536	425595			
	230V ac (2166A-4001T)	425595	89536	425595			
A1A1	Thermometer PCB Assembly (2166A-4001)	425587	89536	425587	1		
A1A2	Point Select PCB Assembly (2166A-4002)	425603	89536	425603	1		
T1	Transformer, Power				1		
	100V ac (2166A-6550)	437624	89536	437624			
	115V ac (2165A-6510	437616	89536	437616			
	230V ac (2165A-6510)	437616	89536	437616			
U4	IC, LSI, digital, P-MOS ⊗	403527	70203	C-10186	1	1	

A1A1 THERMOMETER PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1A1	**THERMOMETER PCB ASSEMBLY (2166A-4001)**	425587	89536	425587	REF		
	Figure 8-1						
C1	Cap, cer, .01 uF ±20%, 3kV	266320	56289	41C301A2	1		
C3, C4, C26	Cap, Ta, 6.8 uF ±20%, 35V	363713	56289	196D685X0035 KA1	3		
C5	Cap, elect, 4700 uF, −10%, +100%, 15V	379370	25088	B41010-4700/16	1	1	
C6,C7, C14, C20, C21, C23, C25	Cap, Ta, 10 uF ±20%, 20V	330662	56289	196D106X0020 JA1	7		
C8	Cap, mica, 100 pF ±1%, 500V	226126	71234	DM15F100F	1		
C9	Cap, mylar, 0.47 uF ±10%, 100V	369124	73445	C280MA/HA47 0K	1		
C10	Cap, disc, 100 pF ±10%, 1kV	105593	71590	DD101	1		
C11	Cap, Ta, 2.2 uF ±10%, 15V	364216	56289	196D222X9015 HA1	1		
C12	Cap, cer, .025 uF ±20%, 100V	168435	56289	C023B101H253H	1		
C13	Cap, polypro, 0.47 uF ±10%, 50V	363085	89536	363085	1		
C15	Cap, cer, 2700 pF ±20%, 100V	362889	72982	8121-A100-W5R-272M	1		
C16	Cap, cer, .0012 uF ±10%, 500V	106732	71590	CF122	1		
C18	Cap, var, 0.25 to 1.5 pF, 2kV	218206	72982	530-000	1	1	
C19	Cap, cer, 1000 pF ±10%, 500V	357806	56289	C106B102G102K	1		
C24	Cap, cer, 1pF, ±0.25 pF, 100V	436477	72982	8101-A100-C0G-109G	1		
CR1	Diode, bridge rectifier	392910	89536	392910	1	1	
CR2	Diode, Si, rectifier	343491	04713	1N4002	1	1	
CR6 thru CR15	Diode, Si, 150 mA, 75V	203323	07910	1N4448	10	2	
F1	Fuse, slo-blo, 1/8A	166488	71400	MDL1-8	1	5	

A1A1 THERMOMETER PCB ASSEMBLY, Cont.

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART. NO. OR TYPE	TOT QTY	REC QTY	USE CDE
J1	Connector, female, 18-pin	435024	00779	583773-8	1		
J2	Connector, post	267500	00779	87022-1	18		
J3, J4	Connector, post	267633	00779	87022-2	12		
Q1 thru Q6, Q8, Q9. Q12, Q14	Xstr, J-FET, N-channel	343830	89536	343830	10	2	
Q10	Xstr, FET, dual N-channel	439703	89536	439703	1	1	
Q11, Q15	Xstr, Si, NPN	218396	04713	2N3904	2	1	
Q13	Xstr, FET, dual N-channel	379321	89536	379321	1	1	
Q20 thru Q23	Xstr, Si, NPN	381798	04713	MPS A-13	4	1	
Q27, Q28	Xstr, Si, NPN	272237	07263	2N4946	2	1	
R1	Res, comp, 430 ±5%, ½W	109058	01121	EB4315	1		
R3	Res, mf, 15.8k ±1%, 1/8W	293668	91637	MFF1-81582F	1		
R4, R6	Res, var cermet 25k ±20%, 1/2W	285213	71450	190PC253B	2	1	
R5	Res, mf, 261k ±1%, 1/8W	257535	91637	MFF1-82613F	1		
R7	Res, mf, 187k ±1%, 1/8W	257469	91637	MFF1-81873F	1		
R8	Res, mf, 2k ±0.1%, 1/8W	340174	91637	MFF1-82001B	1		
R9	Res, mf, 1k ±0.1%, 1/8W	340380	91637	MFF1-81001B	1		
R10	Res, comp, 47k ±5%, 1W	150219	01121	GB4735	1		
R11, R29	Res, comp, 1M ±5%, 1/4W	182204	01121	CB1055	2		
R12	Res, mf, 26.7k ±0.1%, 1/8W	344465	91637	MFF1-82672BS	1		
R16, R17	Res, mf, 14.7k ±1%, 1/8W	226225	91637	MFF1-81472F	2		
R18	Res, comp, 470 ±5%, 1/4W	147983	01121	CB4715	1		
R20	Res, mf, 28.7k ±1%, 1/8W	235176	91637	MFF1-82872F	1		
R21	Res, mf, 61.9k ±1%, 1/8W	237230	91637	MFF1-86192F	1		
R22	Res, mf, 19.1K ±1%, 1/8W	234963	91637	MFF1-81912F	1		
R23	Res, mf, 1k ±1%, 1/8W	168229	91637	MFF1-81001F	1		

A1A1 THERMOMETER PCB ASSEMBLY, Cont.

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
R24, R25	Res, mf, 82.5k ±1%, 1/8W	246223	91637	MFF1-88252F	2		
R26	Res, comp, 680k ±5%, ¼W	188433	01121	CB6845	1		
R27	Res, comp, 100 ±5%, ¼W	147926	01121	CB1015	1		
R28, R33	Res, comp, 220k ±5%, ¼W	160937	01121	CB2245	2		
R30, R32	Res, comp, 20k ±5%, ¼W	221614	01121	CB2035	1		
R39	Res, comp, 2k ±5%, ¼W	202879	01121	CB2025	1		
R40	Res, comp, 22 ±5%, ¼W	147884	01121	CB2205	1		
R41	Res, comp, 330 ±5%, ¼W	147967	01121	CB3315	1		
R43 thru R46	Res, comp, 27k ±5%, ¼W	148148	01121	CB2735	4		
S1,S3	Switch Assembly, push-button	428508	89536	428508	1	1	
S5	Switch, slide	423129	95146	SLS-220-1	1	1	
T2	Xfmr, inverter	436105	89536	436105	1		
U1	IC, dual opnl ampl	404087	49956	RC4739DP	1	1	
U2	IC, opnl ampl	352195	49956	RC311DN	1	1	
U5	IC, TTL, bcd-to-7 segment decoder driver	340109	01295	SN7447N	1	1	
U6	IC, res network, 60Ω	344069	89536	344069	1	1	
U7	IC, C-MOS, Hex Buffer/Inverter ⊗	381830	02735	CD4050AE	1	1	
U8	IC, linear, voltage regulator, +15V	413187	12040	LM340T-18	1	1	
U9	IC, linear, voltage regulator, −12V	381665	04713	MC7912CP	1	1	
U10	IC, linear, voltage regulator, +8V	407627	04713	MC7808CP	1	1	
VR1	Diode, zener, 6.4V ±2%	393579	04713	1N4567	1	1	
VR3	Diode, zener 6.8V	260695	07910	1N754A	1	1	
Y1	Crystal, 400 kHz	403352	89536	403352	1	1	
1	Bushing, snap	102988	28520	SB2502	1		
2	Button, gray	419689	89536	419689	1		
3	Button, green	419747	89536	419747	1		

A1A1 THERMOMETER PCB ASSEMBLY, Cont.

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
4	Connector, ac line						
	Contact, ground	338640	89536	338640	1		
	Contact, voltage	338657	89536	338657	2		
	Insulator, paper	344184	89536	344184	1		
	Insulator, plastic	338624	89536	338624	1		
5	Guide, PCB, nylon	256461	23880	1450-F	2		
6	Shell, isothermal	438093	89536	438093	1		
7	Socket, IC, 40-pin	418988	91506	340-AG37D	1		
8	Heat Sink	352765	98978	PA1-1CB	1		

A1A2 POINT SELECT PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A1A2	**POINT SELECT PCB ASSEMBLY (2166A-4002)**	425603	89536	425603	REF		
	Figure 8-3						
J5	Connector	436022	54453	1SM12DRAS-S 50	1		
P4	Connector, receptacle	267476	00779	85861-2	4		
S1	Switch, Rotary	428110	81073	71BY2310321-10N	1		
	PC Accessory Mount	418897	89536	418897	1		
	Polarizing Insert	407254	54453	ISM-K1			

A2 DISPLAY PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A2	**DISPLAY PCB ASSEMBLY (2165A-4003)** **Figure 8-5**	443515	89536	443515	REF		
DS1, DS2	LED, dual 7-segment character display	419051	29083	MAN 6610	2	1	A
DS3	LED, 7-segment character display	407874	29083	MAN 4610	1	1	A
DS1 thru DS5	LED, 7-segment, numeric display	418012	28480	5082-7651	5	1	B
P4	Connector, female, 16-pin	375329	00779	85863-3	1		
R1	Res, comp, 91 ±5%, 1/4W	221887	01121	CB9105	1		

A3 MULTIPOINT INPUT MODULE

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A3	**MULTIPOINT INPUT MODULE (2166A-4003T)**	425637	89536	425637	REF		
	Figure 8-7						
C1	Cap, cer, 1000 pF ±10%, 500V	357806	56289	C1069102G102K	1		
Q1	Xstr, Si, NPN	329698	07263	2N2484	1	1	
R1	Res, var, 50k ±10%, ½W	330688	80031	ET34-P503	1	1	
R2	Res, mf, 150k ±1%, 1/8W	241083	91637	MFF1-81503F	1		
	Carrier, isothermal	438101	89536	438101	1		
	Clamp, xstr	437756	89536	437756	1		
	Cover, isothermal	438028	89536	438028	1		

A4 TYPE SELECT PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
A4	**TYPE SELECT PCB ASSEMBLY**				REF		
	Figure 8-9						
	R Type (2160A-4012)	415612	89536	415612			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 324 ±1%, 1/8W	423780	91637	MFF1-83240F	1		
R2	Res, mf, 69.5 ±0.1%, 1/8W	423756	91637	MFF1-869R4B	1		
	S Type (2160A-4013)	415620	89536	415620			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 324 ±1%, 1/8W	423780	91637	MFF1-83240F	1		
R2	Res, mf 70 ±0.1%, 1/8W	423764	91637	MFF1-8A700B	1		
	B Type (2160A-4014)	415638	89536	415638			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 143 ±1%, 1/8W	423699	91637	MFF-181430F	1		
	C Type (2160A-4015)	415646	89536	415646			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 590 ±1%, 1/8W	423798	91637	MFF1-85910F	1		
R2	Res, mf, 164.3 ±0.1%, 1/8W	424564	91637	MFF1-8164R3B	1		
	J Type (2160A-4016)	415653	89536	415653			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 10.7k ±1%, 1/8W	423681	91637	MFF1-81072F	1		
R2	Res, mf, 619 ±0.1%, 1/8W	423715	91637	MFF1-86190B	1		
	K Type (2160A-4017	415661	89536	415661			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 3.74k ±1%, 1/8W	260547	91637	MFF1-83741F	1		
R2	Res, mf, 481.4 ± 0.1%, 1/8W	423723	91637	MFF1-8481R4B	1		

A4 TYPE SELECT PCB ASSEMBLY, Cont.

REF DESIG OR ITEM NO.	DESCRIPTION	STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	T Type (2160A-4018)	415927	89536	415927			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 3.74k ±1%, 1/8W	260547	91637	MFF1-83741F	1		
R2	Res, mf, 483.7 ±0.1%, 1/8W	423731	91637	MFF1-8483R7B	1		
	E Type (2160A-4019	415935	89536	415935			
P3	Socket, IC, 8-pin	418608	00779	583640-1	1		
R1	Res, mf, 53.6k ±1%, 1/8W	291401	91637	MFF1-85362F	1		
R2	Res, mf, 732 ±0.1%, 1/8W	423749	91637	MFF1-87320B	1		

Section 6
Option & Accessory Information

6-1. INTRODUCTION

6-2. This section of the manual contains information concerning the Options and Accessories available for use with the Model 2166A Digital Thermometer. The first portion of this section provides a brief description of each option and accessory. The depth of detail is intended to give the prospective user an adequate first aquaintance with the features and capabilities of each. Detailed information concerning specifications, operating instruction, maintenance, list of replaceable parts and schematics is supplied separately with some options and accessories, and is designed to comprise the second portion of this section. Unique page and paragraph numbering is assigned to each of the add-on descriptions to allow separation into easily identifiable subsections. The material is prepunched (T-punched) to permit insertion without disassembling the manual. Table 6-1 lists the available options and accessories and defines the manner in which each is documented.

6-3. CARRYING CASE (C80)

6-4. The Model C80 Carrying Case, Figure 6-1, is a soft vinyl plastic container designed for the storage and transport of the 2166A. The case provides the unit with adequate protection against normal handling and storage conditions. In addition to a shoulder strap, the C80 is equipped with a storage compartment for probes, power cord, and other compact accessories.

Table 6-1. 2166A OPTIONS, ACCESSORIES AND DOCUMENTATION SOURCES

MODEL OR OPTION NO.	DESCRIPTION	DOCUMENTATION SUPPLIED	
		WITH UNIT	HERE IN
C80	Carrying Case		●
C86	Carrying Case		●
TJ36-J	J-Type TC Probe		●
TJ36-K	K-Type TC Probe		●
TJ36-T	T-Type TC Probe		●
M00-100-714	Front Panel Dust Cover		●
M00-200-611	Rack Mtg. Kit, Offset	●	
M00-200-612	Rack Mtg. Kit, Center	●	
M00-200-613	Rack Mtg. Kit, side-by-side	●	
2160A-7016	J-Type Select PCB		●
2160A-7017	K-Type Select PCB		●
2160A-7019	E-Type Select PCB		●
2160A-7018	T-Type Select PCB		●
2160A-7012	R-Type Select PCB		●
2160A-7013	S-Type Select PCB		●
2160A-7014	B-Type Select PCB		●
2160A-7015	C-Type Select PCB		●
2160A-7022	Interface Cable		●
2166A-7010	Multipoint Input Module		●
–02	Digital Output Unit		
–04	Analog Output Unit		

○ = T-punched for insertion in Section 6 of this manual

● = Not T-punched

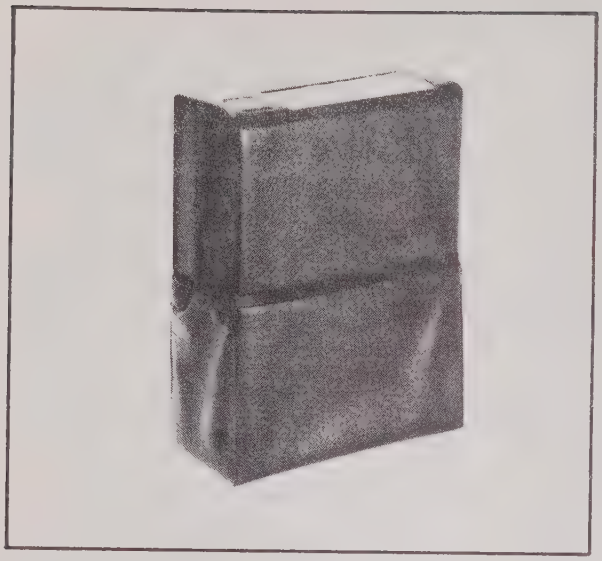

Figure 6-1. C80, CARRYING CASE

6-5. CARRYING CASE (C86)

6-6. The Model C86 Carrying Case, Figure 6-2, is a molded polyethylene container, with handle, designed for use in transporting the 2166A. This rugged case provides the unit with maximum portection against rough handling and adverse weather conditions. A separate storage compartment is provided for probes, power cord, and other compact accessories.

Figure 6-2. C86, CARRYING CASE

6-7. THERMOCOUPLE PROBES

6-8. Three types of thermocouple probe assemblies (J, K and T) are available for use with the 2166A. See Table 6-1. Each thermocouple is enclosed in a 12-inch x 1/8 inch iconel sheath, and includes a heavy duty transition splice and spring. See Figure 6-3. The thermocouple junction is grounded to the sheath, and 36-inch trimmed leads are included on all units. Refer to the Tables under Specifications in Section 1 of this manual for the temperature ranges recommended for each thermocouple type.

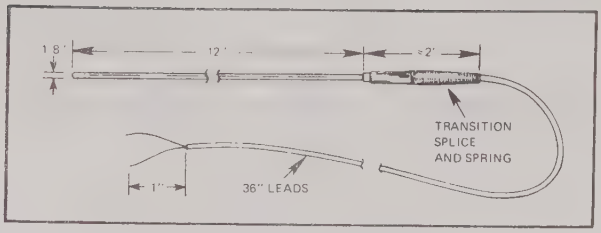

Figure 6-1. TJ36 SERIES THERMOCOUPLE PROBES
(See Catalog and Handbook)

6-9. FRONT PANEL DUST COVER (M00-100-714)

6-10. The front panel dust cover is a molded plastic snap-on accessory which fits over the front panel of the 2166A. The dust cover provides protection for the front panel controls, and is useful when storing or transporting the unit.

6-11. RACK MOUNTING KITS

6-12. Three rack mounting kits are available for mounting the 2166A in a standard 19-inch equipment rack. The kits, listed in Table 6-1, provide the option of either offset mounting (left/right), center mounting or side-by-side mounting.

6-13. TYPE SELECT PCB's

6-14. A series of plug-in type select pcb's are available as accessories to allow the thermocouple compatibility of the 2166A to be changed by the user. The available type select pcb's are listed in Table 6-1, and the instructions necessary to interchange pcb's in the 2166A are given in Section 2 of this manual under Thermocouple Compatibility. Only one of the type select pcb's can be installed in the 2166A at any given time.

6-15. MULTIPOINT INPUT MODULE (2166A-7010)

6-16. The Multipoint Input Module is identical to the input module supplied with the basic 2166A. The use of one or more additional modules is advantageous when it is necessary to measure groups of thermocouples located in different areas. By connecting convenient groups (1-to-10 of the same type thermocouples) of thermocouples to separate Multipoint Input Modules, the 2166A can be used to monitor any given group by plugging in the appropriate module. Details concerning this module are given in the appropriate sections of this manual.

6-17. DIGITAL OUTPUT UNIT, OPTION –02

NOTE

The Digital Output Unit is not operational when the 2166A is powered by an external 12V dc source.

6-18. The Digital Output Unit (Option –02) is a field installable pcb that mounts on the interior of the 2176A and provides a digital output which is equivalent to the displayed measurement data. The digital output is positive-true, TTL compatible and is presented in bcd, character-parallel format. All displayed characters are represented at the output. Output data is solicited by an External Trigger input and valid data is ensured by Busy and $\overline{\text{Busy}}$ outputs.

6-19. External connections to the Digital Output Unit are made through a 34-pin cable which is supplied with the pcb.

6-20. ANALOG OUTPUT UNIT, OPTION –04

NOTE

The Analog Output Unit is not operational when the 2166A is powered by an external 12V dc source.

6-21. The Analog Output Unit is a field installable pcb assembly which provides the 2166A with a rear panel analog output voltage proportional to the displayed measurement data. The output voltage is electrically isolated from the 2166A and covers a voltage range of –0.4 to +4V dc. Automatic polarity sensing is provided for both °C and °F measurements to ensure that the polarity of the output voltage agrees with the displayed polarity. Since the analog output terminals are isolated from the 2166A, the output voltage is referenced to the low terminal of the external recording device (voltmeter, strip-chart recorder, etc.).

6-22. External connections to the Analog Output Unit are made through a connector and cable which is supplied with the pcb.

Section 7
General Information

7-1. This section of the manual contains generalized user information as well as supplemental information to the List of Replaceable Parts contained in Section 5. The following information is presented in this section:

List of Abbreviations

Federal Supply Codes for Manufacturers

List of Abbreviations and Symbols

A or amp	ampere
ac	alternating current
af	audio frequency
a/d	analog-to-digital
assy	assembly
AWG	american wire gauge
B	bel
bcd	binary coded decimal
°C	Celsius
cap	capacitor
ccw	counterclockwise
cer	ceramic
cermet	ceramic to metal(seal)
ckt	circuit
cm	centimeter
cmrr	common mode rejection ratio
comp	composition
cont	continue
crt	cathode-ray tube
cw	clockwise
d/a	digital-to-analog
dac	digital-to-analog converter
dB	decibel
dc	direct current
dmm	digital multimeter
dvm	digital voltmeter
elect	electrolytic
ext	external
F	farad
°F	Fahrenheit
FET	Field-effect transistor
ff	flip-flop
freq	frequency
FSN	federal stock number
g	gram
G	giga (10^9)
gd	guard
Ge	germanium
GHz	gigahertz
gmv	guaranteed minimum value
gnd	ground
H	henry
hd	heavy duty
hf	high frequency
Hz	hertz
IC	integrated circuit
if	intermediate frequency
in	inch(es)
intl	internal
I/O	input/output
k	kilo (10^3)
kHz	kilohertz
kΩ	kilohm(s)
kV	kilovolt(s)
lf	low frequency
LED	light-emitting diode
LSB	least significant bit
LSD	least significant digit
M	mega (10^6)
m	milli (10^{-3})
mA	milliampere(s)
max	maximum
mf	metal film
MHz	megahertz
min	minimum
mm	millimeter
ms	millisecond
MSB	most significant bit
MSD	most significant digit
MTBF	mean time between failures
MTTR	mean time to repair
mV	millivolt(s)
mv	multivibrator
MΩ	megohm(s)
n	nano (10^{-9})
na	not applicable
NC	normally closed
(-) or neg	negative
NO	normally open
ns	nanosecond
opnl ampl	operational amplifier
p	pico (10^{-12})
para	paragraph
pcb	printed circuit board
pF	picofarad
pn	part number
(+) or pos	positive
pot	potentiometer
p-p	peak-to-peak
ppm	parts per million
PROM	programmablle read-only memory
psi	pound-force per square inch
RAM	random-access memory
rf	radio frequency
rms	root mean square
ROM	read-only memory
s or sec	second (time)
scope	oscilloscope
SH	shield
Si	silicon
serno	serial number
sr	shift register
Ta	tantalum
tb	terminal board
tc	temperature coefficient or temperature compensating
tcxo	temperature compensated crystal oscillator
tp	test point
u or μ	micro (10^{-6})
uhf	ultra high frequency
us or μs	microsecond(s) (10^{-6})
uut	unit under test
V	volt
v	voltage
var	variable
vco	voltage controlled oscillator
vhf	very high frequency
vlf	very low frequency
W	watt(s)
ww	wire wound
xfmr	transformer
xstr	transistor
xtal	crystal
xtlo	crystal oscillator
Ω	ohm(s)
μ	micro (10^{-6})

Federal Supply Codes for Manufacturers

00213
Nytronics Comp. Group Inc.
Subsidiary of Nytronics Inc.
Formerly Sage Electronics
Rochester, New York

00327
Welwyn International, Inc.
Westlake, Ohio

00656
Aerovox Corp.
New Bedford, Massachusetts

00666
[illegible]
Jersey

00779
AMP Inc
Harrisburg, Pennsylvania

01121
Allen-Bradley Co.
Milwaukee, Wisconsin

01281
TRW Electronic Comp.
Semiconductor Operations
Lawndale, California

01295
Texas Instruments, Inc.
Semiconductor Group
Dallas, Texas

01537
Motorola Communications &
Electronics Inc.
Franklin Park, Illinois

01686
RCL Electronics Inc.
Manchester, New Hampshire

01730
Replaced by 73586

01884
Use 56289
Sprague Electric Co.
Dearborn Electronic Div.
Lockwood, Florida

02114
Ferroxcube Corp.
Saugerties, New York

02131
General Instrument Corp.
Harris ASW Div.
Westwood, Maine

02395
Rason Mfg. Co.
Brooklyn, New York

02533
Snelgrove, C.R. Co., Ltd.
Don Mills, Ontario, Canada
M3B 1M2

02606
Fenwal Labs
Div. of Travenal Labs.
Morton Grove, Illinois

02660
Bunker Ramo Corp., Conn Div.
Formerly Amphenol-Borg
Electric Corp.
Broadview, Illinois

02799
Areo Capacitors, Inc.
Chatsworth, California

03508
General Electric Co.
Semiconductor Products
Syracuse, New York

03614
Replaced by 71400

03651
Replaced by 44655

03797
Eldema Div.
Genisco Technology Corp.
Compton, California

03877
Transistron Electronic Corp.
Wakefield, Massachusetts

03888
KDI Pyrofilm Corp.
Whippany, New Jersey

03911
Clairex Electronics Div.
Clairex Corp.
Mt. Vernon, New York

03980
Muirhead Inc.
Mountainside, New Jersey

04009
Arrow Hart Inc.
Hartford, Connecticut

04062
Replaced by 72136

04202
Replaced by 81312

04217
Essex International Inc.
Wire & Cable Div.
Anaheim, California

04221
Aemco, Div. of
Midtex Inc.
Mankato, Minnesota

04222
AVX Ceramics Div.
AVX Corp.
Myrtle Beach, Florida

04423
Telonic Industries
Laguna Beach, California

04645
Replaced by 75376

04713
Motorola Inc. Semiconductor
Products
Phoenix, Arizona

04946
Standard Wire & Cable
Los Angeles, California

05082
Replaced by 94988

05236
Jonathan Mfg. Co.
Fullerton, California

05245
Components Corp. now
Corcom, Inc.
Chicago, Illinois

05277
Westinghouse Electric Corp.
Semiconductor Div.
Youngwood, Pennsylvania

05278
Replaced by 43543

05279
Southwest Machine &
Plastic Co.
Glendora, California

05397
Union Carbide Corp.
Materials Systems Div.
New York, New York

05571
Use 56289
Sprague Electric Co.
Pacific Div.
Los Angeles, California

05574
Viking Industries
Chatsworth, California

05704
Replaced by 16258

05820
Wakefield Engineering Inc.
Wakefield, Massachusetts

06001
General Electric Co.
Electronic Capacitor &
Battery Products Dept.
Columbia, South Carolina

06136
Replaced by 63743

06383
Panduit Corp.
Tinley Park, Illinois

06473
Bunker Ramo Corp.
Amphenol SAMS Div.
Chatsworth, California

06555
Beede Electrical Instrument Co.
Penacook, New Hampshire

06739
Electron Corp.
Littleton, Colorado

06743
Clevite Corp.
Cleveland, Ohio

06751
Components, Inc. Semcor Div.
Phoenix, Arizona

06860
Gould Automotive Div.
City of Industry, California

06961
Vernitron Corp., Piezo
Electric Div.
Formerly Clevite Corp., Piezo
Electric Div.
Bedford, Ohio

06980
Eimac Div.
Varian Associates
San Carlos, California

07047
The Ross Milton Co.
South Hampton, Pennsylvania

07115
Replaced by 14674

07138
Westinghouse Electric Corp.,
Electronic Tube Div.
Horsehead, New York

07233
TRW Electronic Components
Cinch Graphic
City of Industry, California

07256
Silicon Transistor Corp.
Div. of BBF Group Inc.
Chelmsford, Massachusetts

07261
Aumet Corp.
Culver City, California

07263
Fairchild Semiconductor
Div. of Fairchild Camera
& Instrument Corp.
Mountain View, California

07344
Bircher Co., Inc.
Rochester, New York

07597
Burndy Corp.
Tape/Cable Div.
Rochester, New York

07792
Lerma Engineering Corp.
Northampton, Massachusetts

07910
Teledyne Semiconductor
Formerly Continental Device
Hawthorne, California

07933
Use 49956
Raytheon Co.
Semiconductor Div. HQ
Mountain View, California

08225
Industro Transistor Corp.
Long Island City, New York

Federal Supply Codes for Manufacturers (cont)

08261
Spectra Strip Corp.
Garden Grove, California

08530
Reliance Mica Corp.
Brooklyn, New York

08806
General Electric Co.
Miniature Lamp Products Dept
Cleveland, Ohio

08863
Nylomatic Corp.
Norrisville, Pennsylvania

08988
Use 53085
Skottie Electronics Inc.
Archbald, Pennsylvania

09214
G.E. Co. Semi-Conductor
Products Dept.
Power Semi-Conductor
Products OPN Sec.
Auburn, New York

09353
C and K Components
Watertown, Massachusetts

09423
Scientific Components, Inc.
Santa Barbara, California

09922
Burndy Corp.
Norwalk, Connecticut

09969
Dale Electronics Inc.
Yankton, S. Dakota

10059
Barker Engineering Corp.
Formerly Amerace, Amerace
ESNA Corp.
Kenilworth, New Jersey

11236
CTS of Berne
Berne, Indiana

11237
CTS Keene Inc.
Paso Robles, California

11358
CBS Electronic Div.
Columbia Broadcasting System
Newburyport, Minnesota

11403
Best Products Co.
Chicago, Illinois

11503
Keystone Columbia Inc.
Warren, Michigan

11532
Teledyne Relays
Hawthorne, California

11711
General Instrument Corp.
Rectifier Division
Hicksville, New York

11726
Qualidyne Corp.
Santa Clara, California

12014
Chicago Rivet & Machine Co.
Bellwood, Illinois

12040
National Semiconductor Corp.
Danburry, Connecticut

12060
Diodes, Inc.
Chatsworth, California

12136
Philadelphia Handle Co.
Camden, New Jersey

12300
Potter-Brumfield Div.
AMF Canada LTD.
Guelph, Ontario, Canada

12323
Presin Co., Inc.
Shelton, Connecticut

12327
Freeway Corp. formerly
Freeway Washer & Stamping Co.
Cleveland, Ohio

12443
The Budd Co. Polychem Products
Plastic Products Div.
Bridgeport, Pennsylvania

12615
U.S. Terminals Inc.
Cincinnati, Ohio

12617
Hamlin Inc.
Lake Mills, Wisconsin

12697
Clarostat Mfg. Co.
Dover, New Hampshire

12749
James Electronics
Chicago, Illinois

12856
Micrometals
Sierra Madre, California

12954
Dickson Electronics Corp.
Scottsdale, Arizona

12969
Unitrode Corp.
Watertown, Massachusetts

13103
Thermalloy Co., Inc.
Dallas, Texas

13327
Solitron Devices Inc.
Tappan, New York

13511
Amphenol Cadre Div.
Bunker-Ramo Corp.
Los Gatos, California

13606
Use 56289
Sprague Electric Co.
Transistor Div.
Concord, New Hampshire

13839
Replaced by 23732

14099
Semtech Corp.
Newbury Park, California

14140
Edison Electronic Div.
Mc Gray-Edison Co.
Manchester, New Hampshire

14193
Cal-R-Inc. formerly
California Resistor, Corp.
Santa Monica, California

14298
American Components, Inc.
an Insilco Co.
Conshohocken, Pennsylvania

14655
Cornell-Dublier Electronics
Division of Federal Pacific
Electric Co. Govt. Control Dept.
Newark, New Jersey

14752
Electro Cube Inc.
San Gabriel, California

14869
Replaced by 96853

14936
General Instrument Corp.
Semi Conductor Products Group
Hicksville, New York

15636
Elec-Trol Inc.
Saugus, California

15801
Fenwal Electronics Inc.
Div. of Kidde Walter and Co., Inc.
Framingham, Massachusetts

15818
Teledyne Semiconductors,
formerly Amelco Semiconductor
Mountain View, California

15849
Litton Systems Inc. Useco Div.
formerly Useco Inc.
Van Nuys, California

15898
International Business
Machines Corp.
Essex Junction, Vermont

15909
Replaced by 14140

16258
Space-Lok Inc.
Burbank, California

16299
Corning Glass
Electronic Components Div.
Raleigh, North Carolina

16332
Replaced by 28478

16473
Cambridge Scientific Ind.
Div. of Chemed Corporation
Cambridge, Maryland

16742
Paramount Plastics
Fabricators, Inc.
Downey, California

16758
Delco Electronics
Div. of General Motors Corp.
Kokomo, Indiana

17001
Replaced by 71468

17069
Circuit Structures Lab.
Burbank, California

17338
High Pressure Eng. Co., Inc.
Oklahoma City, Oklahoma

17545
Atlantic Semiconductors, Inc.
Asbury Park, New Jersey

17856
Siliconix, Inc.
Santa Clara, California

17870
Replaced by 14140

18178
Vactec Inc.
Maryland Heights, Missouri

18324
Signetics Corp.
Sunnyvale, California

18612
Vishay Resistor Products Div.
Vishay Intertechnology Inc.
Malvern, Pennsylvania

18736
Voltronics Corp.
Hanover, New Jersey

18927
GTE Sylvania Inc.
Precision Material Group
Parts Division
Titusville, Pennsylvania

19451
Perine Machinery & Supply Co.
Seattle, Washington

19701
Electro-Midland Corp.
Mepco-Electra Inc.
Mineral Wells, Texas

20584
Enochs Mfg. Inc.
Indianapolis, Indiana

Federal Supply Codes for Manufacturers (cont)

20891
Self-Organizing Systems, Inc.
Dallas, Texas

21604
Bucheye Stamping Co.
Columbus, Ohio

21845
Solitron Devices Inc.
Transistor Division
Riveria Beach, Florida

22767
ITT Semiconductors
Palo Alto, California

23050
Product Comp. Corp.
Mount Vernon, New York

23732
Tracor Inc.
Rockville, Maryland

23880
Stanford Applied Engrng.
Santa Clara, California

23936
Pamotor Div., Wm. J. Purdy Co.
Burlingame, California

24248
Replaced by 94222

24355
Analog Devices Inc.
Norwood, Massachusetts

24655
General Radio
Concord, Massachusetts

24759
Lenox-Fugle Electronics Inc.
South Plainfield, New Jersey

25088
Siemen Corp.
Isilen, New Jersey

25403
Amperex Electronic Corp.
Semiconductor &
Micro-Circuits Div.
Slatersville, Rhode Island

27014
National Semiconductor Corp.
Santa Clara, California

27264
Molex Products
Downers Grove, Illinois

28213
Minnesota Mining & Mfg. Co.
Consumer Products Div.
St. Paul, Minnesota

28425
Serv-/-Link formerly
Bohannan Industries
Fort Worth, Texas

28478
Deltrol Controls Div.
Deltrol Corporation
Milwaukee, Wisconsin

28480
Hewlett Packard Co.
Corporate HQ
Palo Alto, California

28520
Heyman Mfg. Co.
Kenilworth, New Jersey

29083
Monsanto, Co., Inc.
Santa Clara, California

29604
Stackpole Components Co.
Raleigh, North Carolina

30148
AB Enterprise Inc.
Ahoskie, North Carolina

30323
Illinois Tool Works, Inc.
Chicago, Illinois

31091
Optimax Inc.
Colmar, Pennsylvania

32539
Mura Corp.
Great Neck, New York

32767
Griffith Plastic Corp.
Burlingame, California*

32879
Advanced Mechanical
Components
Northridge, California

32897
Erie Technological Products, Inc.
Frequency Control Div.
Carlisle, Pennsylvania

32997
Bourns Inc.
Trimpot Products Division
Riverside, California

33173
General Electric Co.
Products Dept.
Owensboro, Kentucky

34333
Silicon General
Westminister, California

34335
Advanced Micro Devices
Sunnyvale, California

34802
Electromotive Inc.
Kenilworth, New Jersey

37942
P.R. Mallory & Co., Inc.
Indianapolis, Indiana

42498
National Radio
Melrose, Massachusetts

43543
Nytronics Inc.
Transformer Co. Div.
Geneva, New York

44655
Ohmite Mfg. Co.
Skokie, Illinois

49671
RCA Corp.
New York, New York

49956
Raytheon Company
Lexington, Massachusetts

50088
Mostek Corp.
Carrollton, Texas

50579
Litronix Inc.
Cupertino, California

51605
Scientific Components Inc.
Linden, New Jersey

53021
Sangamo Electric Co.
Springfield, Illinois

54294
Cutler-Hammer Inc. formerly
Shallcross, A Cutter-Hammer Co.
Selma, North Carolina

55026
Simpson Electric Co.
Div. of Am. Gage and Mach. Co.
Elgin, Illinois

56289
Sprague Electric Co.
North Adams, Massachusetts

58474
Superior Electric Co.
Bristol, Connecticut

60399
Torin Corp. formerly
Torrington Mfg. Co.
Torrington, Connecticut

63743
Ward Leonard Electric Co., Inc.
Mount Vernon, New York

64834
West Mfg. Co.
San Francisco, California

65092
Weston Instruments Inc.
Newark, New Jersey

66150
Winslow Tele-Tronics Inc.
Eaton Town, New Jersey
70485
Atlantic India Rubber Works
Chicago, Illinois

70563
Amperite Company
Union City, New Jersey

70903
Belden Corp.
Geneva, Illinois

71002
Birnback Radio Co., Inc.
Freeport, New York

71400
Bussmann Mfg.
Div. of McGraw-Edison Co.
Saint Louis, Missouri

71450
CTS Corp.
Elkhart, Indiana

71468
ITT Cannon Electric Inc.
Santa Ana, California

71482
Clare, C.P. & Co.
Chicago, Illinois

71590
Centrelab Electronics
Div. of Globe Union Inc.
Milwaukee, Wisconsin

71707
Coto Coil Co., Inc.
Providence, Rhode Island

71744
Chicago Miniature Lamp Works
Chicago, Illinois

71785
TRW Electronics Components
Cinch Connector Operations Div.
Elk Grove Village
Chicago, Illinois

72005
Wilber B. Driver Co.
Newark, New Jersey

72092
Replaced by 06980

72136
Electro Motive Mfg. Co.
Williamantic, Connecticut

72259
Nytronics Inc.
Pelham Manor, New Jersey

72619
Dialight Div.
Amperex Electronic Corp.
Brooklyn, New York

72653
G.C. Electronics
Div. of Hydrometals, Inc.
Brooklyn, New York

72665
Replaced by 90303
72794
Dzus Fastener Co., Inc.
West Islip, New York

72928
Gulton Ind. Inc.
Gudeman Div.
Chicago, Illinois

Federal Supply Codes for Manufacturers (cont)

72982
Erie Tech. Products Inc.
Erie, Pennsylvania

73138
Bechman Instrument Inc.
Helipot Division
Fullerton, California

73293
Hughes Aircraft Co.
Electron Dynamics Div.
Torrance, California

73445
Amperex Electronic Corp.
Hicksville, New York

73559
Carling Electric Inc.
West Hartford, Connecticut

73586
Circle F Industries
Trenton, New Jersey

73734
Federal Screw Products, Inc.
Chicago, Illinois

73743
Fischer Special Mfg. Co.
Cincinnati, Ohio

73899
JFD Electronics Co.
Components Corp.
Brooklyn, New York

73949
Guardian Electric Mfg. Co.
Chicago, Illinois

74199
Quan Nichols Co.
Chicago, Illinois

74217
Radio Switch Corp.
Marlboro, New Jersey

74276
Signalite Div.
General Instrument Corp.
Neptune, New Jersey

74306
Piezo Crystal Co.
Carlisle, Pennsylvania

74542
Hoyt Elect. Instr. Works
Penacook, New Hampshire

74970
Johnson E.F., Co.
Waseca, Minnesota

75042
TRW Electronics Components
IRC Fixed Resistors
Philadelphia, Pennsylvania

75376
Kurz-Kasch Inc.
Dayton, Ohio

75378
CTS Knights Inc.
Sandwich, Illinois

75382
Kulka Electric Corp.
Mount Vernon, New York

75915
Littlefuse Inc.
Des Plaines, Illinois

76854
Oak Industries Inc.
Switch Div.
Crystal Lake, Illinois

77342
AMF Inc.
Potter & Brumfield Div.
Princeton, Indiana

77638
General Instrument Corp.
Rectifier Division
Brooklyn, New York

77969
Rubbercraft Corp. of CA. LTD.
Torrance, California

78189
Shakeproof
Div. of Illinois Tool Works Inc.
Elgin, Illinois

78277
Sigma Instruments, Inc.
South Braintree, Massachusetts

78488
Stackpole Carbon Co.
Saint Marys, Pennsylvania

78553
Eaton Corp. Engineered
Fastener Div.
Tinnerman Plant
Cleveland, Ohio

79136
Waldes Kohinoor Inc.
Long Island City, New York

79497
Western Rubber Company
Goshen, Indiana

79963
Zierick Mfg. Corp.
Mt. Kisko, New York

80031
Electro-Midland Corp.
Mepco Div.
A North American Phillips Co.
Norristown, New Jersey

80145
LFE Corp., Process Control Div.
formerly API Instrument Co.
Chesterland, Ohio

80183
Use 56289
Sprague Products
North Adams, Massachusetts

80294
Bourns Inc., Instrument Div.
Riverside, California

80583
Hammarlund Mfg. Co., Inc.
Red Bank, New Jersey

80640
Arnold Stevens, Inc.
South Boston, Massachusetts

81073
Grayhill, Inc.
La Grange, Illinois

81312
Winchester Electronics
Div. of Litton Industries Inc.
Oakville, Connecticut

81483
Therm-O-Disc Inc.
Mansfield, Ohio

81483
International Rectifier Corp.
Los Angeles, California

81590
Korry Mfg. Co.
Seattle, Washington

81741
Chicago Lock Co.
Chicago, Illinois

82305
Palmer Electronics Corp.
South Gate, California

82389
Switchcraft Inc.
Chicago, Illinois

82415
North American Phillips
Controls Corp.
Frederick, Maryland

82872
Roanwell Corp.
New York, New York

82877
Rotron Inc.
Woodstock, New York

82879
ITT Royal Electric Div.
Pawtucket, Rhode Island

83003
Varo Inc.
Garland, Texas

83058
The Carr Co., United Can Div.
of TRW
Cambridge, Massachusetts

83298
Bendix Corp.
Electric Power Div.
Eatontown, New Jersey

83330
Herman H. Smith, Inc.
Brooklyn, New York

83478
Rubbercraft Corp.
of America, Inc.
West Haven, Connecticut

83594
Burroughs Corp.
Electronic Components Div.
Plainfield, New Jersey

83740
Union Carbide Corp.
Battery Products Div.
formerly Consumer Products Div.
New York, New York

84171
Arco Electronics
Great Neck, New York

84411
TRW Electronic Components
TRW Capacitors
Ogallala, Nebraska

84613
Fuse Indicator Corp.
Rockville, Maryland

84682
Essex International Inc.
Industrial Wire Div.
Peabody, Massachusetts

86577
Precision Metal Products
of Malden Inc.
Stoneham, Massachusetts

86684
Radio Corp. of America
Electronic Components Div.
Harrison, New Jersey

86928
Seastrom Mfg. Co., Inc.
Glendale, California

87034
Illuminated Products Inc.
Subsidiary of Oak Industries Inc.
Anahiem, California

88219
Gould Inc.
Industrial Div.
Trenton, New Jersey

88245
Litton Systems Inc.
Useco Div.
Van Nuys, California

88419
Cornell-Dubilier Electronic Div.
Federal Pacific Co.
Fuquay-Varian, North Carolina

88486
Plastic Wire & Cable
Jewitt City, Connecticut

88690
Replaced by 04217

89536
John Fluke Mfg. Co., Inc.
Seattle, Washington

89730
G.E. Co., Newark Lamp Works
Newark, New Jersey

Federal Supply Codes for Manufacturers (cont)

90201
Mallory Capacitor Co.
Div. of P.R. Mallory Co., Inc.
Indianapolis, Indiana

90211
Use 56365
Square D Co.
Chicago, Illinois

90215
Best Stamp & Mfg. Co.
Kansas City, Missouri

90303
Mallory Battery Co.
Div. of Mallory Co., Inc.
Tarrytown, New York

91094
Essex International Inc.
Suglex/IWP Div.
Newmarket, New Hampshire

91293
Johanson Mfg. Co.
Boonton, New Jersey

91407
Replaced by 58474

91502
Associated Machine
Santa Clara, California

91506
Augat Inc.
Attleboro, Massachusetts

91637
Dale Electronics Inc.
Columbus, Nebraska

91662
Elco Corp.
Willow Grove, Pennsylvania

91737
Use 71468
Gremar Mfg. Co., Inc.
ITT Cannon/Gremar
Santa Ana, California

91802
Industrial Devices, Inc.
Edgewater, New Jersey

91833
Keystone Electronics Corp.
New York, New York

91836
King's Electronics Co., Inc.
Tuckahoe, New York

91929
Honeywell Inc.
Micro Switch Div.
Freeport, Illinois

91934
Miller Electric Co., Inc.
Div. of Aunet
Woonsocket, Rhode Island

92194
Alpha Wire Corp.
Elizabeth, New Jersey

93332
Sylvania Electric Products
Semiconductor Products Div.
Woburn, Massachusetts

94145
Replaced by 49956

94154
Use 94988
Wagner Electric Corp.
Tung-Sol Div.
Newark, New Jersey

94222
Southco Inc. formerly
South Chester Corp.
Lester, Pennsylvania

95146
Alco Electronic Products Inc.
Lawrence, Massachusetts

95263
Leecraft Mfg. Co.
Long Island City, New York

95264
Replaced by 98278

95275
Vitramon Inc.
Bridgeport, Connecticut

95303
RCA Corp.
Receiving Tube Div.
Cincinnati, Ohio

95348
Gordo's Corp.
Bloomfield, New Jersey

95354
Methode Mfg. Corp.
Rolling Meadows, Illinois

95712
Bendix Corp.
Electrical Components Div.
Microwave Devices Plant
Franklin, Indiana

95987
Weckesser Co. Inc.
Chicago, Illinois

96733
San Fernando Electric Mfg. Co.
San Fernando, California

96853
Gulton Industries Inc.
Measurement and Controls Div.
formerly Rustrak Instruments Co.
Manchester, New Hampshire

96881
Thomson Industries, Inc.
Manhasset, New York

97540
Master Mobile Mounts, Div. of
Whitehall Electronics Corp.
Ft. Meyers, Florida

97913
Industrial Electronic
Hardware Corp.
New York, New York

97945
Penwalt Corp.
SS White Industrial Products Div.
Piscataway, New Jersey

97966
Replaced by 11358

98094
Replaced by 49956

98159
Rubber-Teck, Inc.
Gardena, California

98278
Malco A Microdot Co., Inc.
Connector & Cable Div.
Pasadena, California

98291
Sealectro Corp.
Mamaroneck, New York

98388
Royal Industries
Products Div.
San Diego, California

98743
Replaced by 12749

98925
Replaced by 14433

99120
Plastic Capacitors, Inc.
Chicago, Illinois

99217
Bell Industries Elect.
Comp. Div.
formerly Southern Elect. Div.
Burbank, California

99392
STM
Oakland, California

99515
ITT Jennings Monrovia Plant
Div. of ITT Jennings formerly
Marshall Industries Capacitor Div.
Monrovia, California

99779
Use 29587
Bunker-Ramo Corp.
Barnes Div.
Landsdowne, Pennsylvania

99800
American Precision Industries Inc.
Delevan Division
East Aurora, New York

99942
Centrelab Semiconductor
Centrelab Electronics Div. of
Globe-Union Inc.
El Monte, California

Toyo Electronics
(R-Ohm Corp.)
Irvine, California

National Connector
Minneapolis, Minnesota

Section 8
Schematic Diagrams

FIGURE NO.	NAME	DRAWING NO.	PAGE
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8-9.	A4 Type Select PCB Assembly Component Location	(2160A-1612)	8-10
8-10.	A4 Type Select PCB Assembly Schematic	(2160A-1012)	8-10

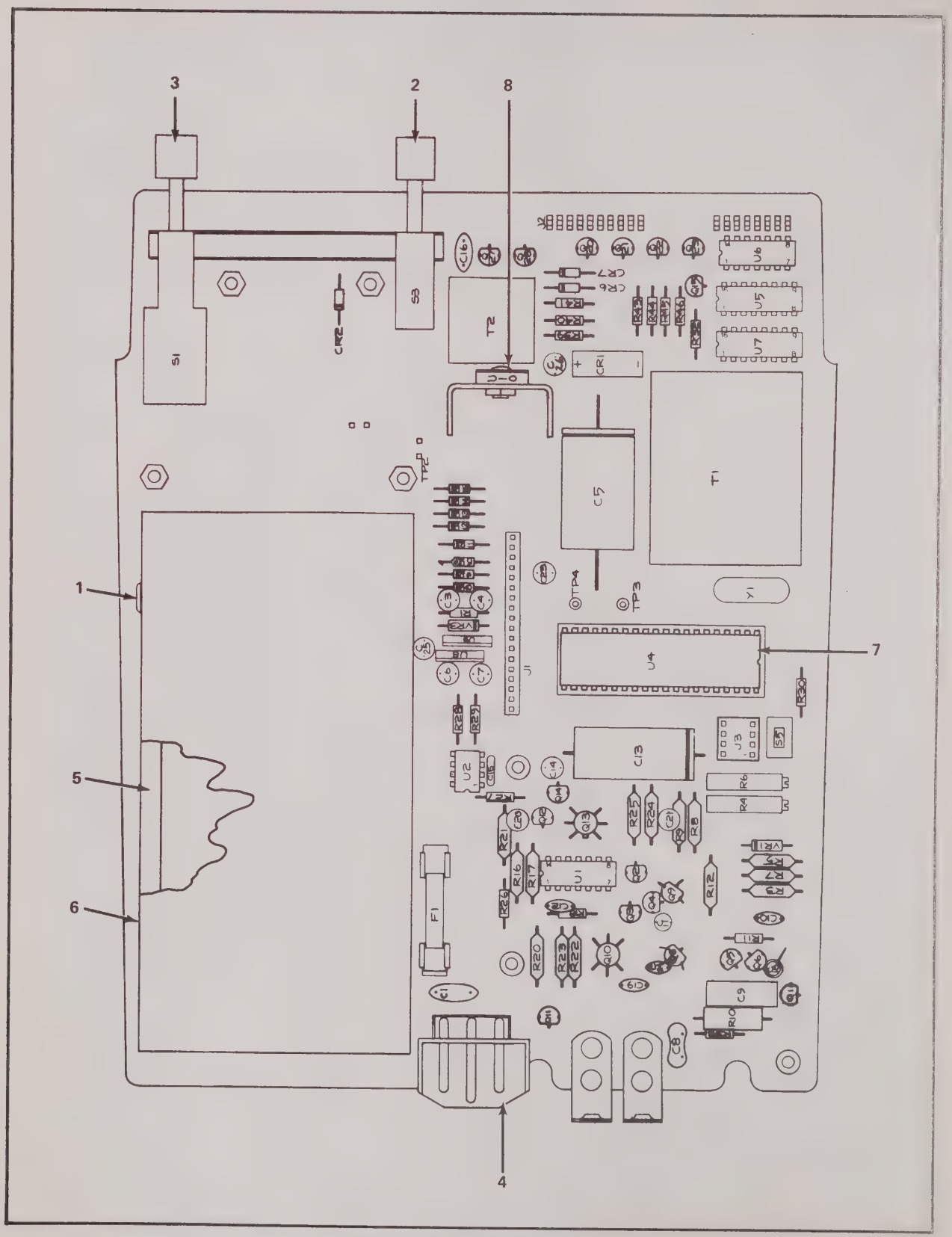


Figure 8-1. A1A1 THERMOMETER PCB ASSEMBLY COMPONENT LOCATION (2166A-1601)

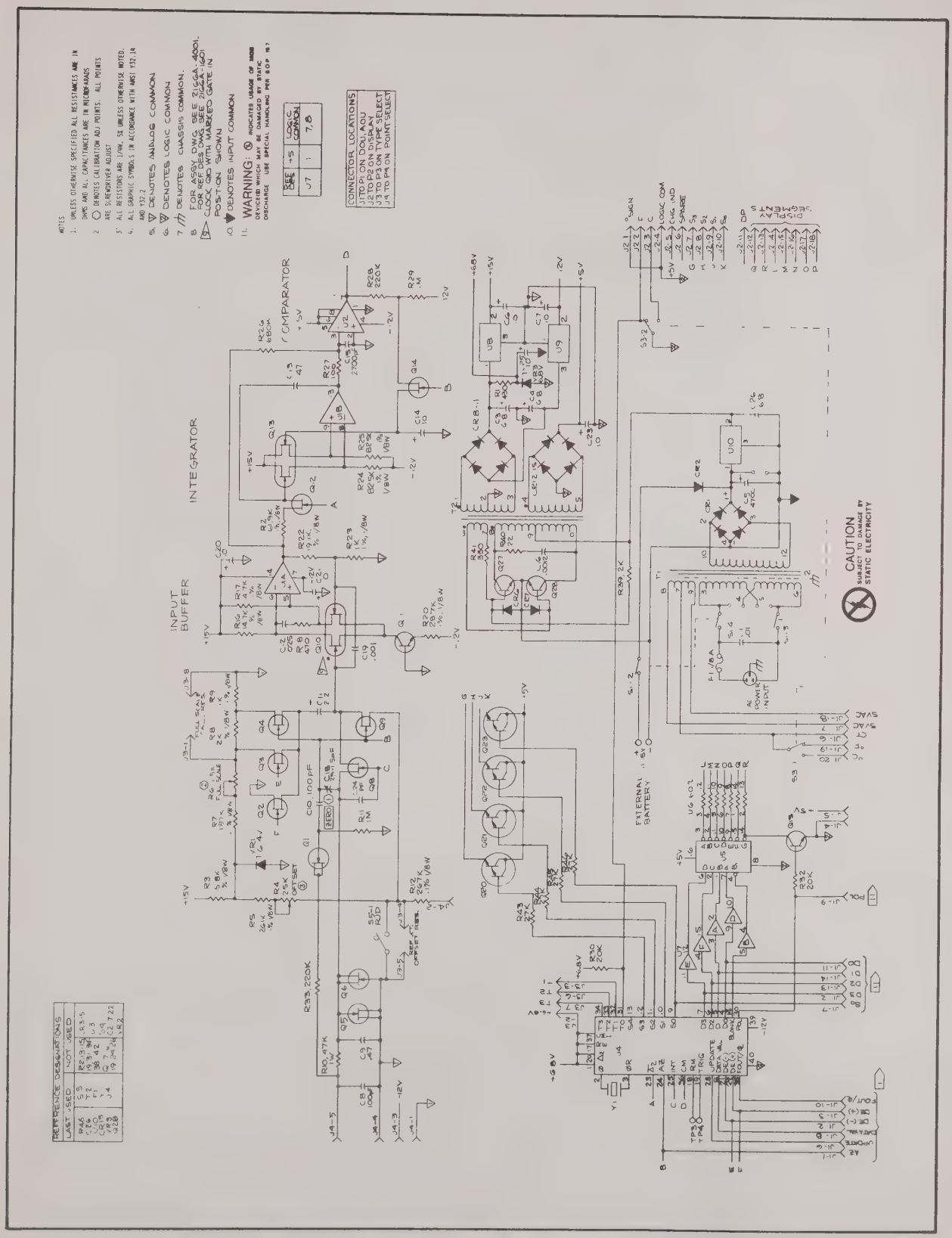

NOTES
1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS
2. ○ DENOTES CALIBRATION ADJ POINTS. ALL POINTS ARE SCREWDRIVER ADJUST
3. ALL RESISTORS ARE 1/4W, 5% UNLESS OTHERWISE NOTED.
4. ALL GRAPHIC SYMBOLS IN ACCORDANCE WITH ANSI Y32.14 AND Y32.2
5. ▽ DENOTES ANALOG COMMON
6. ▽ DENOTES LOGIC COMMON
7. DENOTES CHASSIS COMMON.
8. FOR ASSY DWG SEE 2166A-4001. FOR REF DES DWG SEE 2166A-1001
9. CLOCK GND WITH MARKED GATE IN POSITION SHOWN
10. ▼ DENOTES INPUT COMMON
11. WARNING: ⊗ INDICATES USAGE OF MOS DEVICES WHICH MAY BE DAMAGED BY STATIC DISCHARGE. USE SPECIAL HANDLING PER SOP 163
CONNECTOR LOCATIONS
J1 TO P1 ON DOU, AOU
J2 TO P2 ON DISPLAY
J3 TO P3 ON TYPE SELECT
J4 TO P4 ON POINT SELECT
REFERENCE DESIGNATIONS
LAST USED
NOT USED
INPUT BUFFER
INTEGRATOR
COMPARATOR
EXTERNAL BATTERY
CAUTION
SUBJECT TO DAMAGE BY STATIC ELECTRICITY

Figure 8-2. A1A1 THERMOMETER PCB ASSEMBLY SCHEMATIC (2166A-1001)

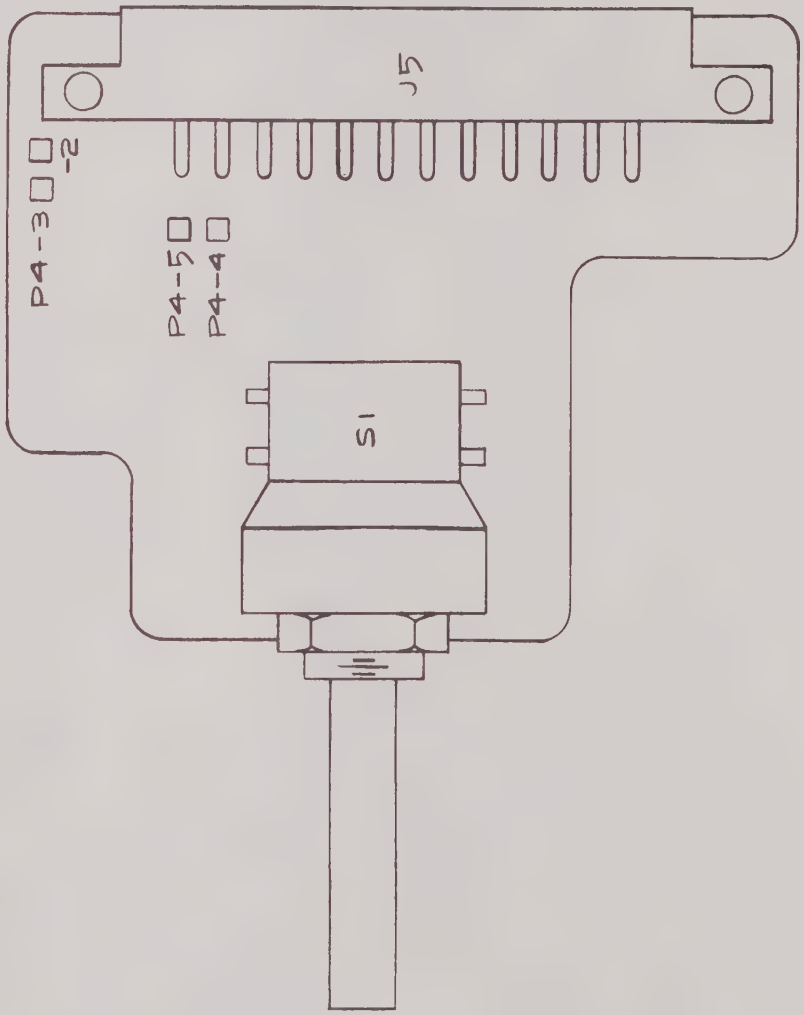


Figure 8-3. A1A2 POINT SELECT PCB ASSEMBLY COMPONENT LOCATION (2166A-1602)

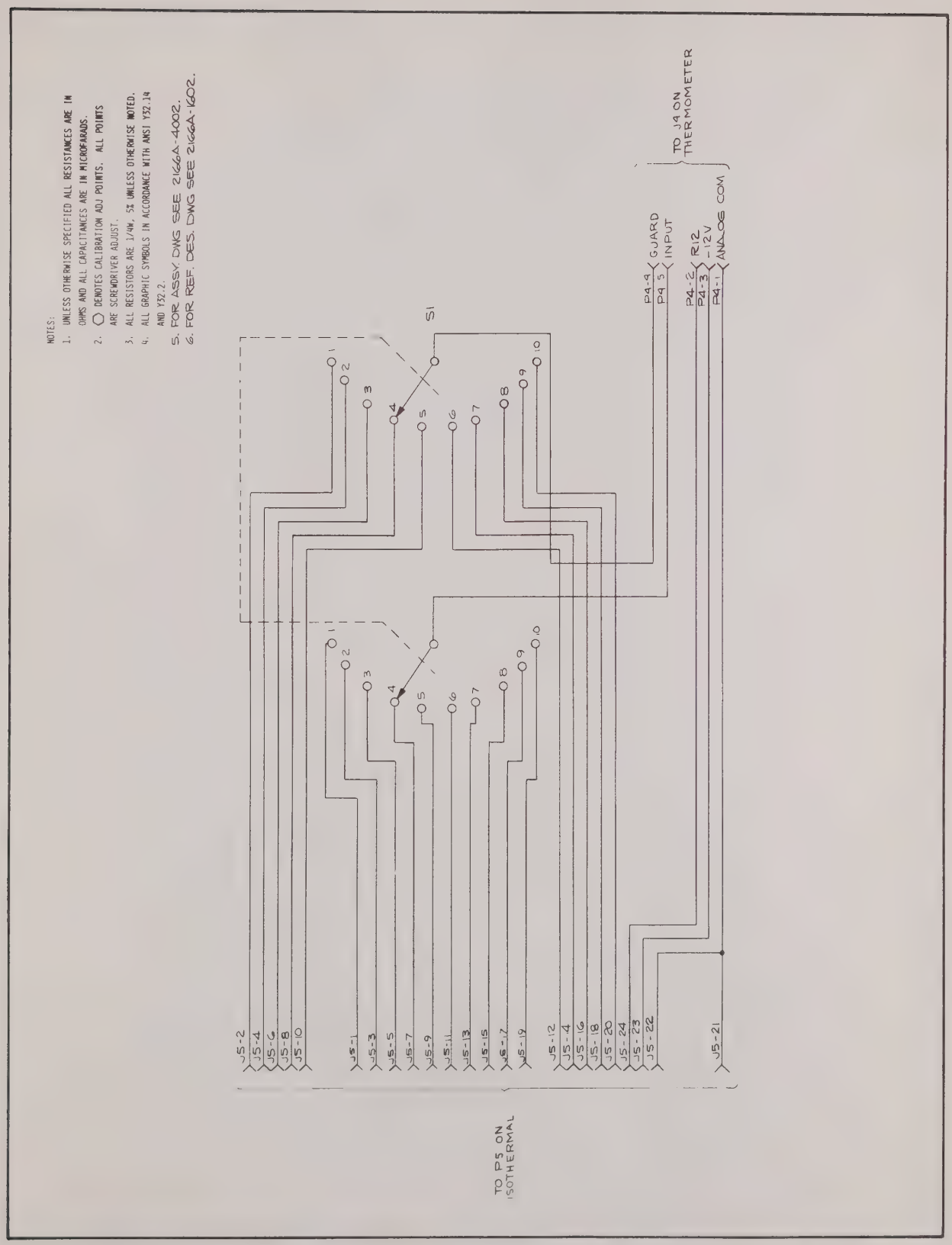


Figure 8-4. A1A2 POINT SELECT PCB ASSEMBLY SCHEMATIC (2166A-1002)

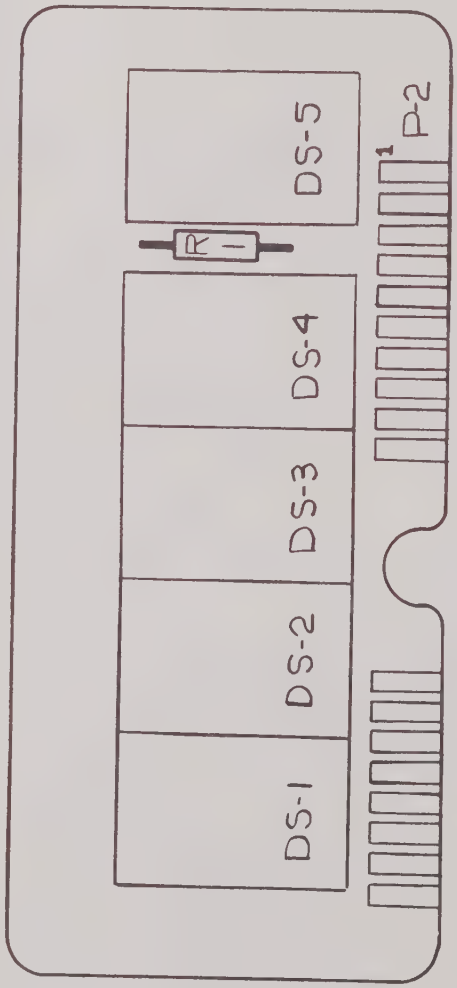
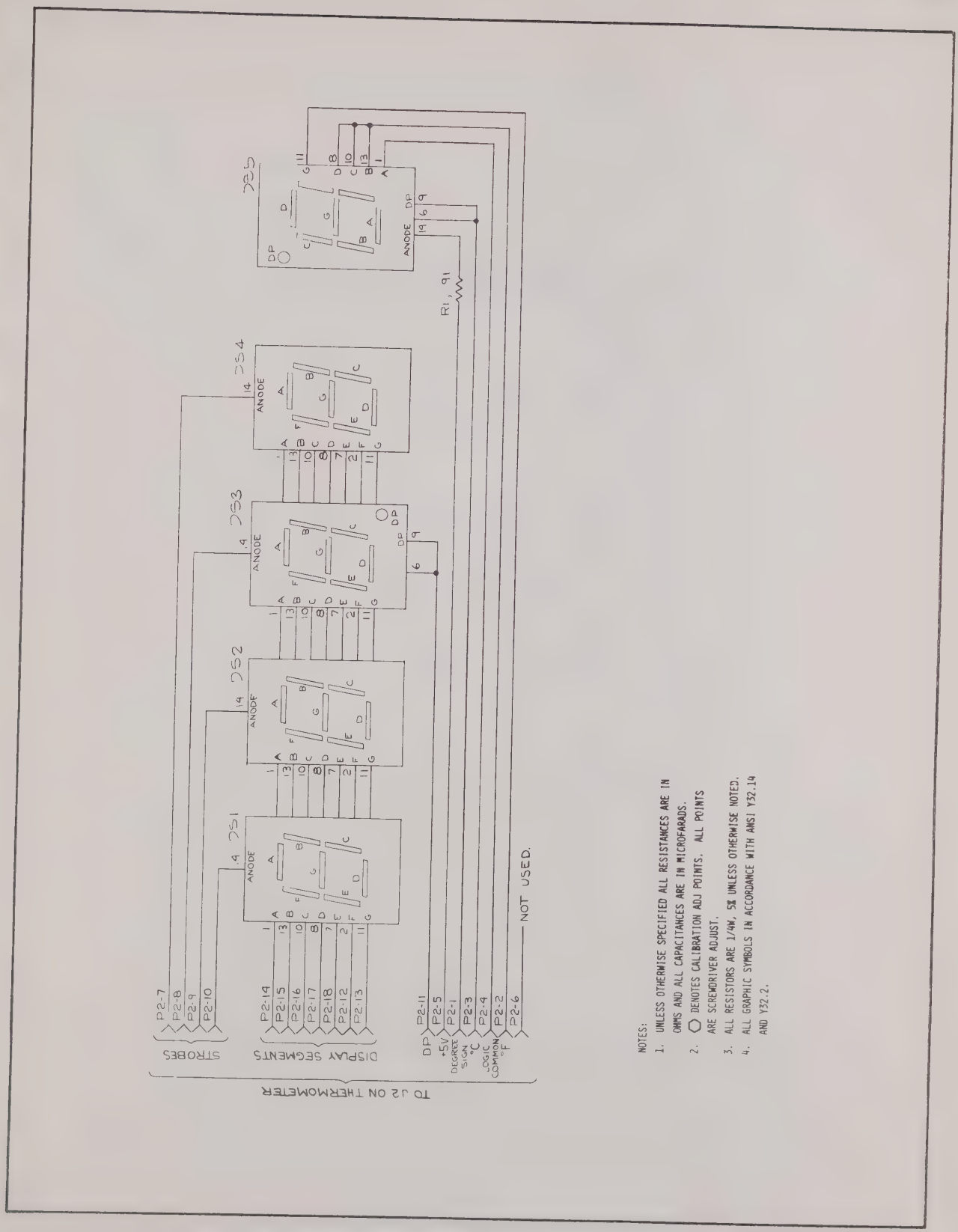


Figure 8-5. A2 DISPLAY PCB ASSEMBLY COMPONENT LOCATION (2165A-1603)



NOTES:

1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCES ARE IN OHMS AND ALL CAPACITANCES ARE IN MICROFARADS.
2. ⬡ DENOTES CALIBRATION ADJ POINTS. ALL POINTS ARE SCREWDRIVER ADJUST.
3. ALL RESISTORS ARE 1/4W, 5% UNLESS OTHERWISE NOTED.
4. ALL GRAPHIC SYMBOLS IN ACCORDANCE WITH ANSI Y32.14 AND Y32.2.

Figure 8-6. A2 DISPLAY PCB ASSEMBLY SCHEMATIC (2165A-1003)

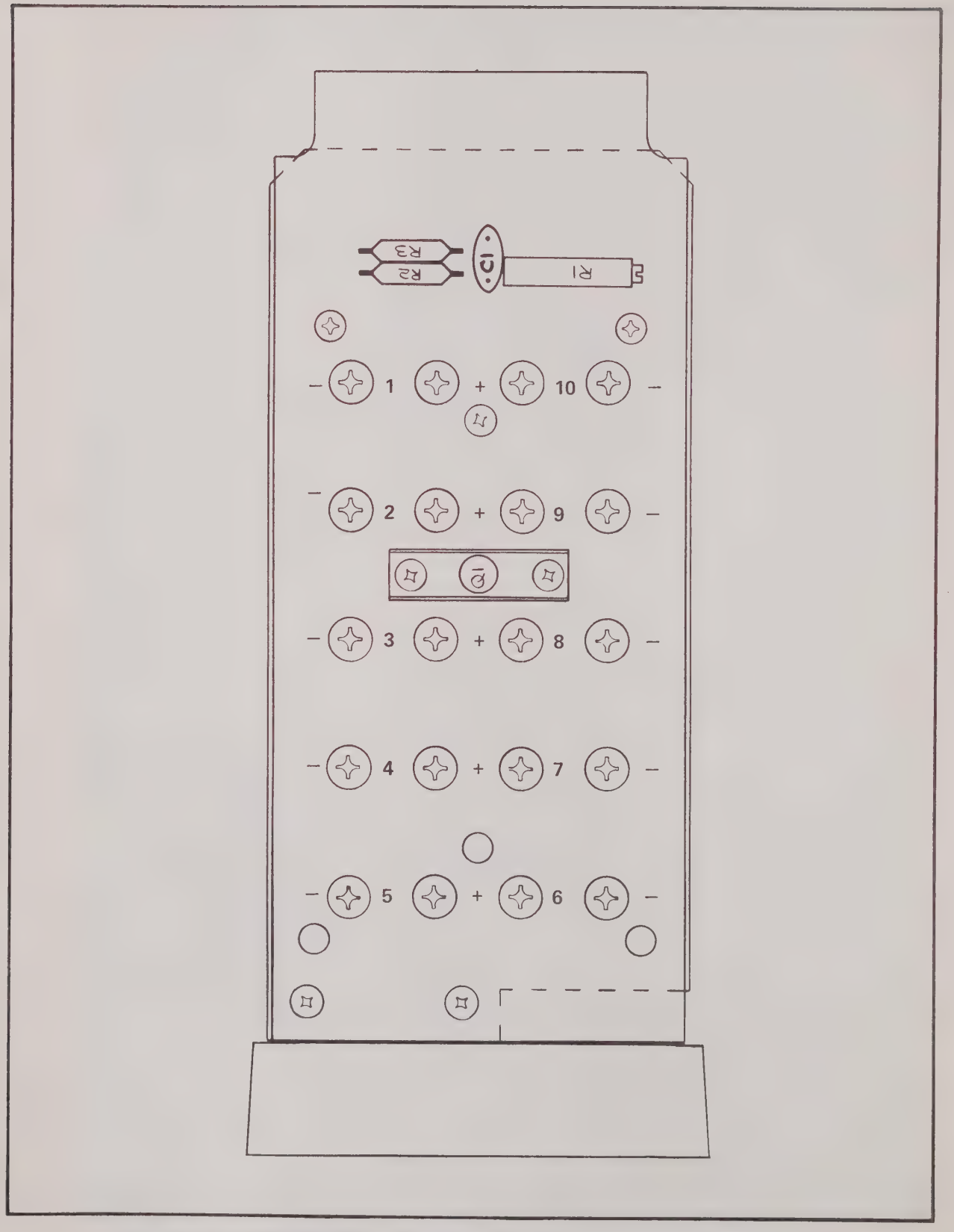


Figure 8-7. A3 MULTIPOINT INPUT MODULE COMPONENT LOCATION (2166A-1603)

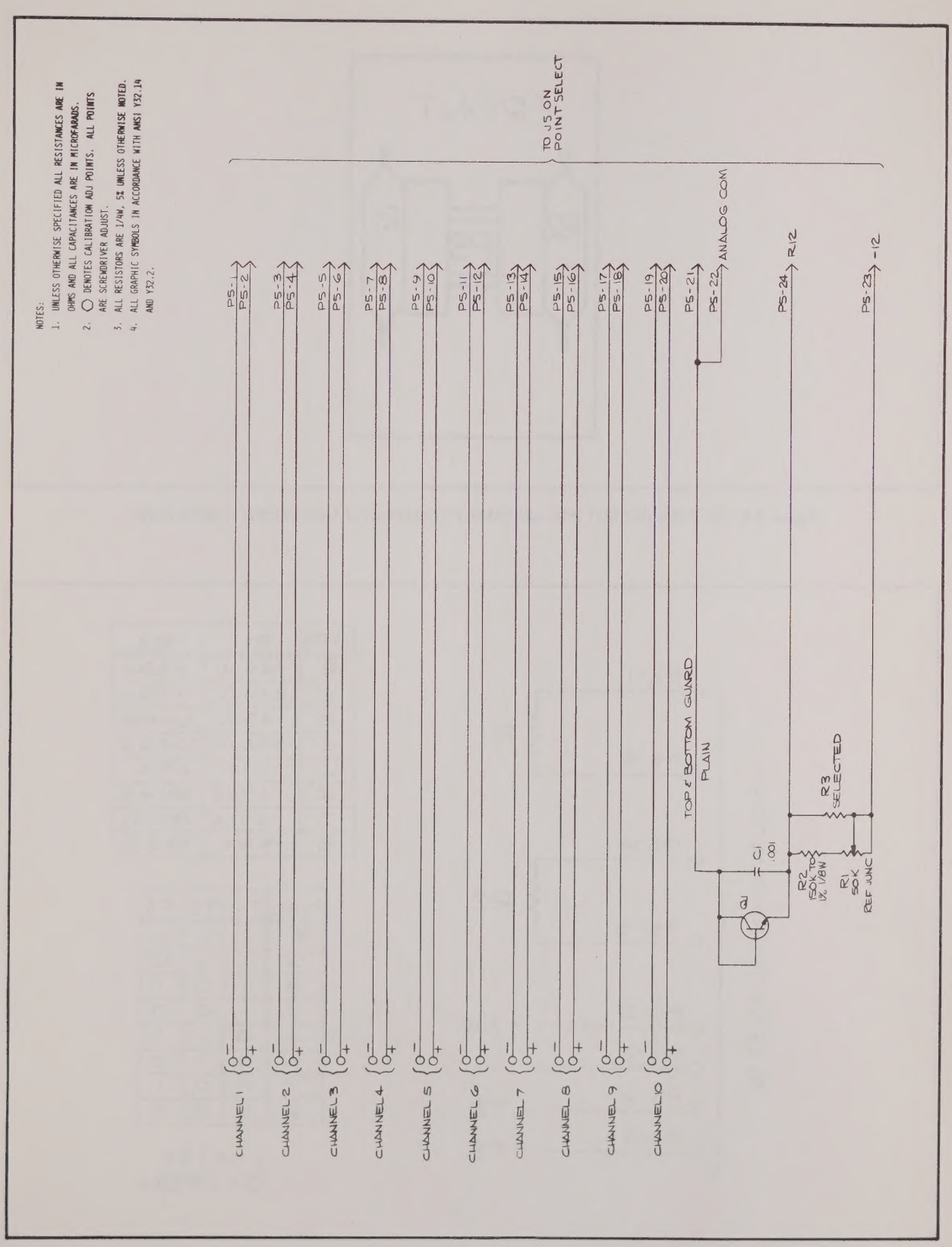


Figure 8-8. A3 MULTIPOINT INPUT MODULE SCHEMATIC (2166A-1003)

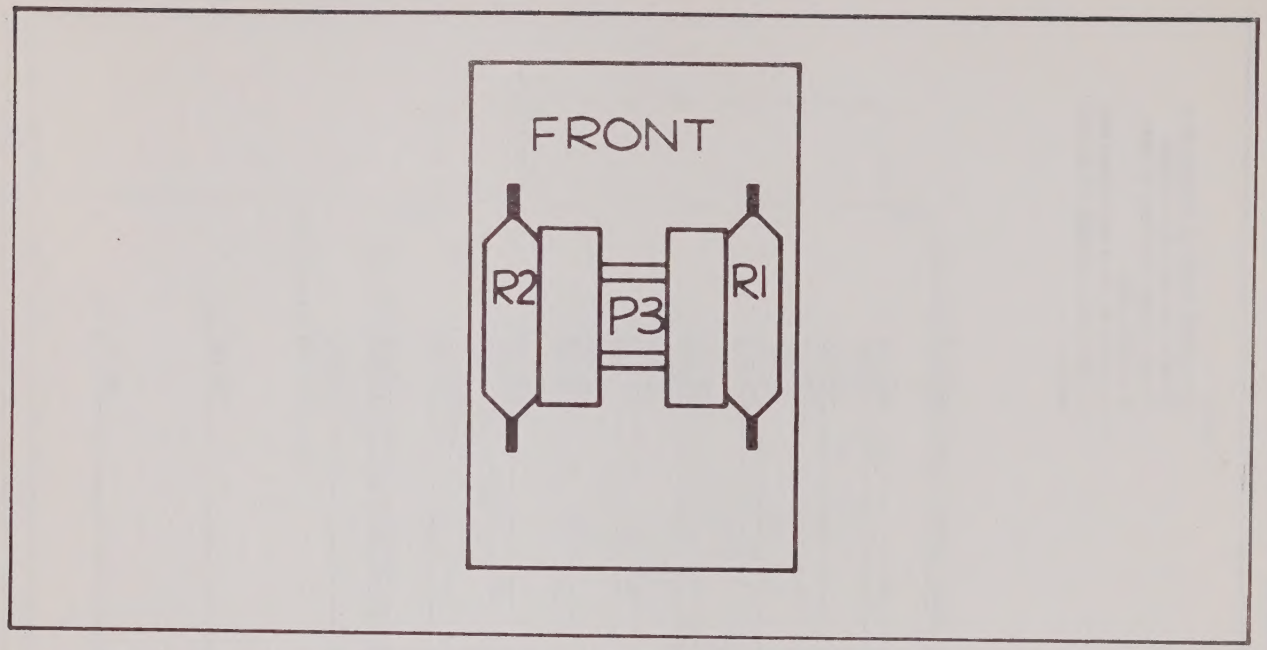
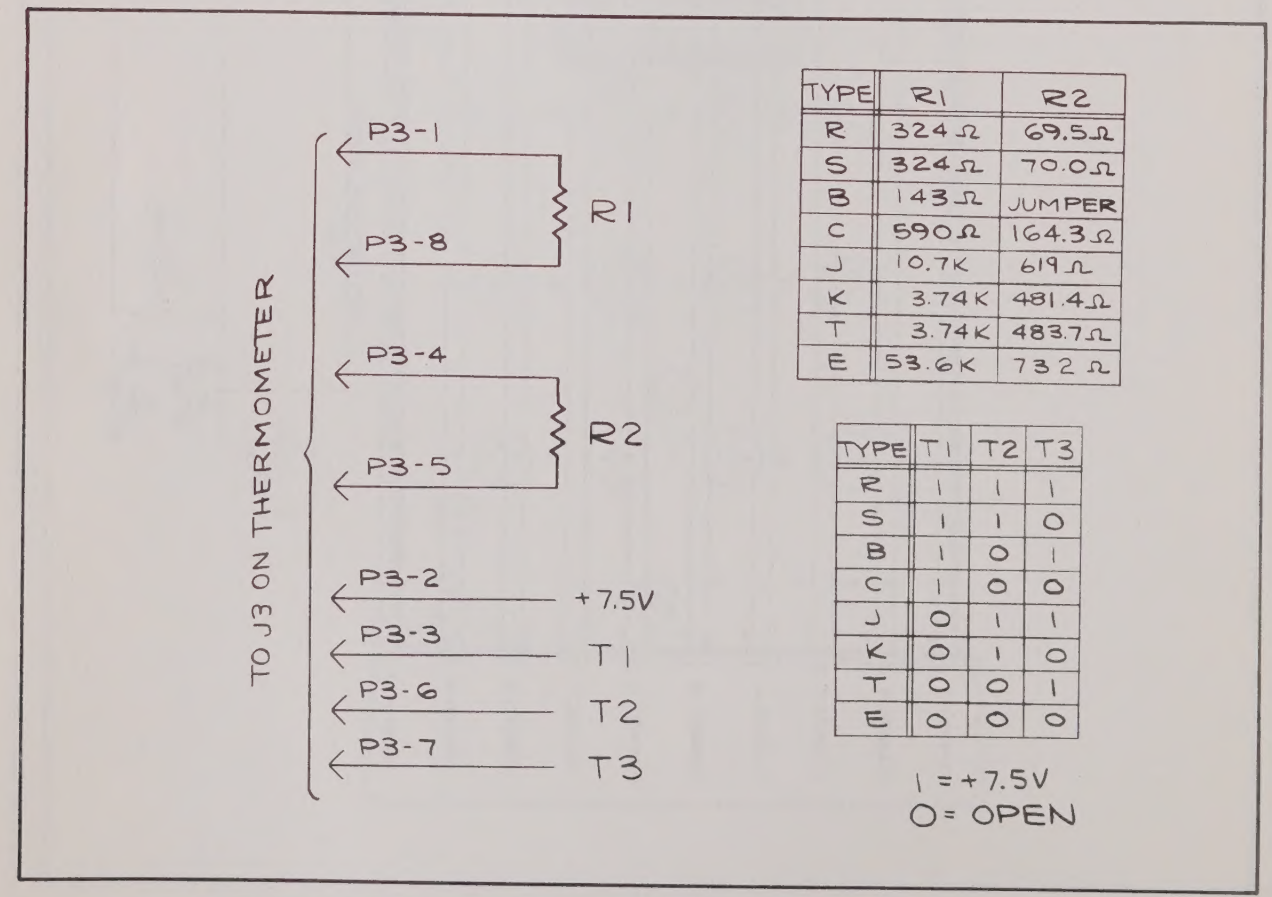


Figure 8-9. A4 TYPE SELECT PCB ASSEMBLY COMPONENT LOCATION (2160A-1612)

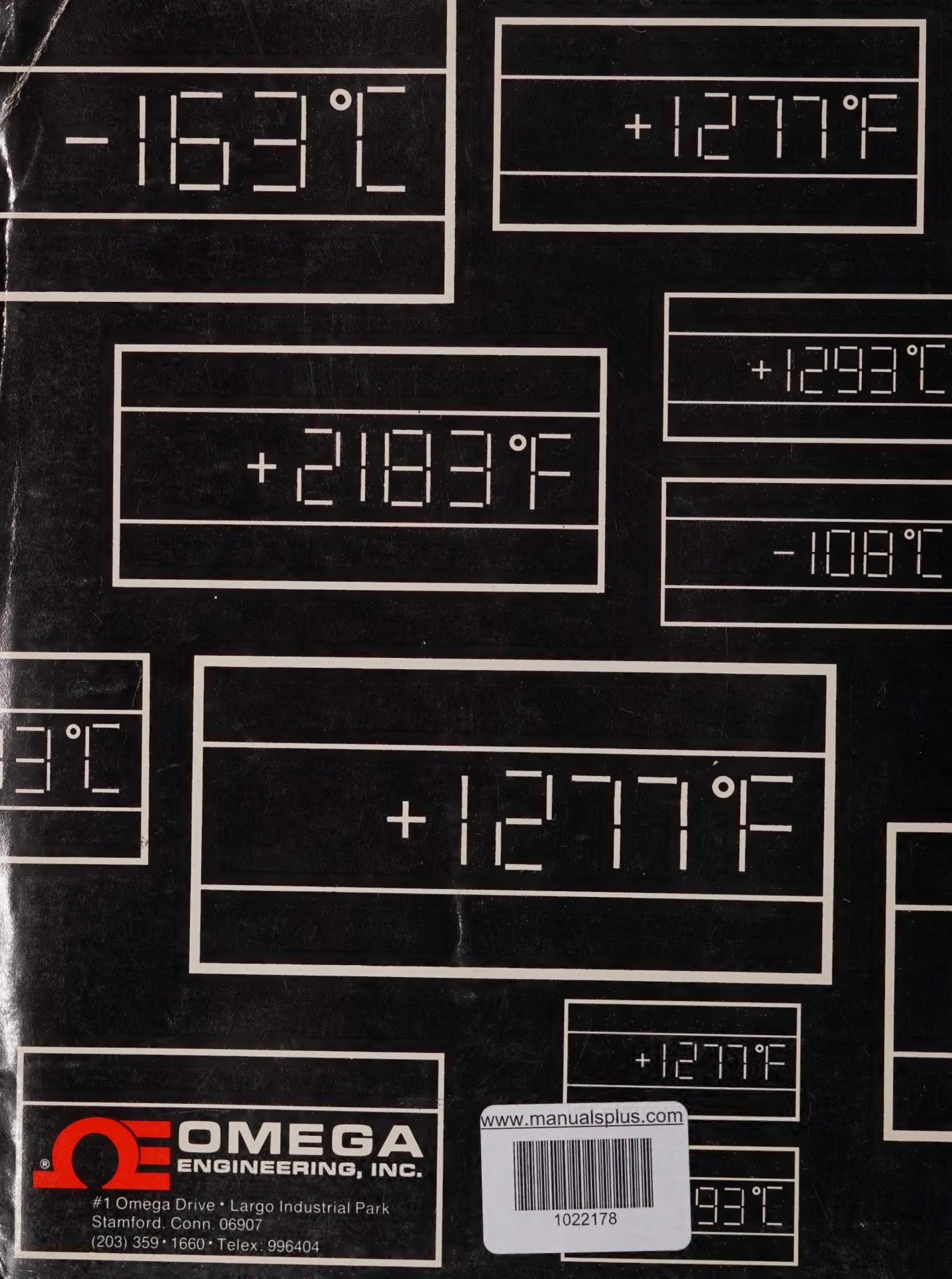


TYPE	R1	R2
R	324Ω	69.5Ω
S	324Ω	70.0Ω
B	143Ω	JUMPER
C	590Ω	164.3Ω
J	10.7K	619Ω
K	3.74K	481.4Ω
T	3.74K	483.7Ω
E	53.6K	732Ω

TYPE	T1	T2	T3
R	1	1	1
S	1	1	0
B	1	0	1
C	1	0	0
J	0	1	1
K	0	1	0
T	0	0	1
E	0	0	0

1 = +7.5V
0 = OPEN

Figure 8-10. A4 TYPE SELECT PCB ASSEMBLY SCHEMATIC (2160A-1012)



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